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CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Description of a Portable Coffer Dam used at Fort Taylor, Key West, 1861, and of a proposed new Tremis. By Captain E. B. HUNT, Corps of Engineers, U. S. A.

IN the *Journal of the Franklin Institute*, December, 1860, is published a discussion of this dam, in anticipation of its use. Having now given it a fair trial, and having found its value very great in the case I have had in hand, a more precise account of its arrangement and working is presented.

Coffer dams are usually *fixed*, and consist of two or more sheathings between which a puddled wall is packed. In Daniel Stevenson's so-called Portable Coffer used in the River Ribble, the dam had to be taken apart and put together again when moved. No case of a really portable coffer has come to my knowledge. The Fort Taylor dam is movable without dismemberment, being dragged endwise from section to section of the wall. It has been used in depths up to six feet, and I have no doubt but it can be worked in very much deeper water.

The novel principle in this dam is in the use of a canvas sheathing of the coffer and of the end adjacent to the bottom edge of the coffer. The pumping of the enclosed space brings the pressure of the water to bear on the canvas, which sucks tight to the coffer and bottom, thus cutting off all flow of water except such as may enter at the outer edge of and flow under the canvas flap spread on the bottom.

The bottom along the line of wall now built, is a compact and some-

what irregular ledge of oolitic island stone, covered with from two feet to an inch of mud, sand, &c. This rock is soft enough to admit the driving in it of iron bars by sledges. After careful consideration, I determined to build the coffer of a series of horizontal wales, separated by blocking permanently sheathed with tongued and grooved inch boards, making a bottomless box with water-tight sides. At one end the timber was carried up solidly, and a set of cross-ties bonded together with the wales, to give a rigid support for the pumping apparatus. The wales and blocking were bored for a set of two-inch round iron bars to be driven into the rock as piles and to receive the side pressures, thus saving all need of cross bracing in this instance. The outer dimensions of the box are 50 by 22 feet, and the included wall is 8 feet thick. Each section is 41 feet long, of concrete entirely, and having a slope of 45 degrees in the upper section of 6 feet high. When no special difficulties are encountered, one of these sections is made in from three to four days, including the moving of coffer and preparation for the next section, or at the best, two sections in a week complete.

The canvas case and flap are simply good No. 2 cotton duck of single thickness. I first had the flap made 20 feet wide, but have reduced this to 10 feet. Along the bottom angle, I have had a second thickness sewed on, one breadth wide, half being on the case and half on the flap. This is the part chiefly subject to wear and strain. In the first section, the case and flap were complete. In the second, one end was split along the middle, and the opening was closed around the end of the first section. A movable bulkhead was made which can be adjusted to the cross-section of the wall. Drag ropes on the outer edge of the flap facilitate its manœuvre in the water, and in greater depths will be the main reliance. It has been necessary to contend with a strong tidal current. A very important point is to have a quantity of sand bags to throw down on the edge of the flap, and along the bottom of the coffer. These bring the canvas to its bearing and can never harm it by irregular strains. They are easily recovered prior to moving, and indeed, each bag may have its own cord with buoyed end, so that they can be used very freely at considerable depths. The case is lightly tacked to the coffer, and eased off from the top when a severe strain by pressure requires. In one instance, inattention to this caution caused the canvas to split and flood the enclosure; such damages are, however, easily repaired by the sail-maker. In fitting the end around the cross profile of the last section, much care is required, the chief leakages having been encountered there. Light india rubber cloth yielding to slight pressures, has served a good purpose here.

The pumping apparatus consists simply of four barrel-pumps worked by the walking beams and driven by a six horse power portable engine, the same which has been used for hoisting on the Fort and made at the Columbian Foundry, N. Y., which supplied the pumps and driving wheels all ready for use. Only the frame had to be made here. This is bolted on the wales and has been moved with the coffer, engine, and all, by simply slinging the pumps. These are furnished with shoes

to rest on the bottom, which lift the pump some six inches to keep it clear of stones, &c. The moving is managed by two shear poles, scarfed together at the top, holding the lifting purchase at one end of a forty-ton scow, the hoisting being done by a crab-purchase on the deck. By thus lifting the pump end of the coffer with all its fixtures, the whole is handled endwise by leading a tackle to an anchor carried out ahead in line. In deep water it moves with great ease. The iron piles are drawn, and the concrete platform struck, at each move. This platform is most conveniently made by carrying a trestle cap parallel to one side, and some 18 feet to 20 feet from it: then using cross stringers and covering plank with close joints in the part where the concrete is mixed. The materials are brought by barrows on runways carried by trestles. I have got up a set of nipping barrows, which are a great convenience and saving, in moving barrels of stone, sand, and cement. They consist simply of the common barrow wheel and two side arms joined at the wheel end by a stiff iron bow spring over the wheel, and banded around the ends of these arms where the wheel pintels pass through them. Two rows of three or four strong sharp teeth take hold of the barrel where these arms are strided over it towards the bottom, it being on end. A thin iron crossbar made to slide in a mortise of one of the arms and fixed in the other, holds the barrel from the wheel. This simple barrow enables men with ease to wheel open barrels to the coffer platform.

The concrete frame within the coffer serves its purpose perfectly well. It consists of two main sills and five profile frames, arranged to hold the plank suspended over the slope. The concrete packed against these gives a good smooth surface. Two of these forms are used, to avoid waiting, while the last section sets. They are first stayed to the coffer, but before moving, weights are put on to prevent floating up, and cleaving from the concrete, which, besides injuring the surface, will open leaks into the new section.

In two sections a very bad bottom was encountered, composed largely of stones, only partly packed in sand. The flap resting on this bed could not of course prevent the water from washing the sand out, and leaving only open stones. A sheathing was here driven down outside the coffer, and thus the coffer was cleared and settled. The flap was rolled up, and the bottom cleared of stones, until the rock was finally reached, when the canvas immediately shaped itself to it and sucked tight. Twelve sections have now been put in, each being entirely founded on the clear rock. In two of these, angles were turned without difficulty.

There is no difficulty in using the purchase on the scow before described for hoisting stones from a wharf, carrying them suspended to the coffer, over the side, lowering in place, and bedding, as perfectly as on dry land. The concrete backing of granite faced walls will thus easily be carried up with the courses, and the whole wall will be quickly built in sections as long as the coffer space.

When much sand is brought up by the pumps, it will be judicious to use spouts for leading the discharged water well away from the flap,

as else it will be found hard to remove the deposited sand. Having thus far had a negro force, which in this mild climate can dive and work in the water for a considerable time without suffering, this precaution has not been required, though I can see its necessity in greater depths and colder waters.

In building concrete walls in the water, this plan offers great advantages over any other. There is a saving of at least 10 per cent. by using the large stone fragments, which can be imbedded as in dry concrete work. There is no loss of cement by passing through water, which will I suppose be from 5 to 10 per cent. in most cases of lowered concrete. The concrete is much better, being well rammed and homogeneous. This is shown by its surfaces, which come out quite sound and smooth, as they never would be in box or tremis work. The facility of execution is quite unequalled. The bottom is perfectly cleared. For granite walls backed with concrete, the economy and advantages are even greater. The headers and streachers can thus be just as well bedded as on dry land. The serious wear and tear of health by diving-bell work is quite avoided, and the water is so easily cleared that operations have all the regularity of dry land masonry labor, night work being wholly avoided.

The experience thus far acquired leads me to regard this canvas or flexible water-proofing as a most valuable extension of building methods. It is indeed a new *principle* of *practice*, which will by ingenious application lend itself to a great variety of cases. It will require judgment to decide whether any particular case favors its use, but with careful study there need be no mistakes. Experience only can limit the depths at which it can be applied. By augmenting strength with pressure, it can go indefinitely deep. Some bottoms would at once prohibit its application. Smooth rock and hard clay will be favorable. I have tried it in sand, and it has succeeded, though much care is required. By using well jointed sheathing, well set up, the plan will work even in soft mud. By giving a slight flare downwards to the coffer, it can be settled within the sheathing. It will not be hard to decide when iron pile supports must give place to or be helped by cross bracing. It is one great advantage of this method of operation, that no great array of preparation is exposed to destruction by storms or accidents. By building the wall thus in solid complete sections, nothing but the dam is exposed. This, as has been shown, will safely bear a considerable sea. A free use of old ship bolts has made the coffer very strong, even though it has some pliability. It was used during the swell of a norther, which would have ruined any coffer depending on puddling. In important works iron sheathing might be preferable, though plank well used are sufficient for most cases. In some instances here, the irregularities of bottom, when using the permanently nailed sheathing, has given gaps of over six inches to be bridged by the canvas, and it has successfully done it. In such cases I have used straw bags, sand bags, and sod scraps to relieve this undue strain, by chinking the holes, before spreading the canvas.

I will suggest an improved tremis, related to this coffer. Instead of

the heavy box spout, through which to pass the concrete under water, I propose a simple canvas spout, made like the trunk of a windsail, and fastened to a top frame; at the bottom end let a circular or square flap be sewed on. Before immersing, a cord is so tied, at the bottom end, that it can be unknotted by pulling from above. As the trunk goes down, it is collapsed. Begin throwing in concrete at top, until it is sufficiently filled for releasing the bottom stricture; then unknot the cord, and continue throwing in concrete. It will spread out because of the pressure, under the flap at bottom, filling the space and raising the flap, with almost no water contact. By drag ropes attached to this flap, the bottom of the tremis can be easily lifted as the filling proceeds, and shifted when it is done. We can give to such a tremis any desired strength, by using several thicknesses of canvas. By making the flap a little larger than the section area, the section might be filled without any water contact, the water being simply lifted as the filling proceeds. Certainly the gain in simplicity and economy offered by such a tremis, entitles it to trial, when work of this kind is to be done.

FORT TAYLOR, KEY WEST, Dec. 2, 1861.

Iron-clad Steamers.—Report of the Naval Board on the Stevens Battery.

WASHINGTON, Dec. 31, 1861.

The board of naval and scientific gentlemen appointed by the Secretary of the Navy, agreeably to a resolution of Congress, to examine the Stevens Battery, have, after a long and thorough investigation, reported as follows:—

NAVY YARD, BROOKLYN, Dec. 24, 1861.

SIR—In obedience to orders from the Navy Department, appointing the undersigned members of a board to examine the iron steam battery now building at Hoboken, N. J., and ascertain what will be the cost of completing the same, how soon it can be completed, and the expediency thereof, we met at this place on the 1st ult., and entered upon the above duties by examining so much of the battery as has already been constructed, and by desiring Mr. Stevens to furnish us with plans and descriptions of the vessel as she would be when completed and ready for service.

These latter were received on the 15th inst., previous to which the board had visited the battery frequently; and, having carefully examined the vessel as far as advanced, and the plans submitted for her completion, we beg leave respectfully to

REPORT:—That we found upon the grounds of Mr. Stevens, at Hoboken, situated in an excavation or dock, a long, slender iron vessel, in an unfinished state, evidently intended for high speed in smooth water.

DESCRIPTION OF THE PORTION ALREADY BUILT.

Hull.—The shell of the vessel is completed up to a height of twenty-one feet from the bottom, but without the decks or beams upon which they are to rest. This vessel is 420 feet long by 45 feet extreme breadth. The iron plating, with the exception of a keel plate, which is ten inches wide and one inch thick, and the garboard streaks, which are thirty inches wide and five-eighths of an inch thick, is half-inch thick, riveted to ribs of angle iron six inches deep, three inches wide, and one-half inch thick, a similar angle iron, reversed, being riveted to each rib. These ribs are spaced two feet apart throughout the entire length. Extending across the bottom of the vessel, at each rib, are floor timbers two feet deep, formed of plate iron one-half inch thick, along the lower edge of which is riveted the angle iron ribs, and along the top edge of which is riveted the reversed angle iron.

Boilers.—Upon fore and aft keelsons, of box form, made of plate iron six inches in depth, and fastened to the tops of the floor timbers, are placed two horizontal fire tube boilers, with the tubes over the furnaces. The boilers are arranged similarly to those in our large naval vessels—namely, five on each side with one fire room amidships, running fore and aft, common to both sides. These boilers occupy eighty feet of the length of the vessel, commencing one hundred and twenty-four feet from the stem. Within these boilers are thirty furnaces, with tubes of two and a half inches diameter, and ranging from seven feet to eight and a half in length, placed over them. The shells of the boilers are one-quarter of an inch thick, single riveted, with stays one and a quarter inches diameter, placed twelve inches apart, attached to crow feet, the toes of which are six inches apart, thus staying the flat surfaces every six inches. They contain, in the aggregate, 876 square feet of grate surface, and 28,000 square feet of fire surface as follows:

Tubes,	23,380	sq. feet.
Furnaces,	2,050	"
Connexions,	1,890	"
Tube sheets,	680	"
Total,	28,000	"

Engines.—Immediately abaft the boilers are the main engines, eight in number, already in a nearly completed state, occupying the whole breadth and depth of the present structure for a length of fifty-three feet. There are two propeller shafts, with four engines upon each, so arranged that each propeller is quite independent of the other. The engines are vertical, overhead beam, condensing engines, having common jet condensers, with vertical air pumps, one condenser and air pump serving for two engines. Each cylinder is forty-five and three-fourths inches diameter by three and one-half feet stroke of piston.

The crank shaft of each engine is forged separately, with cranks and crank pins forged on. These shafts are then connected together by a rigid coupling in such a manner that the entire shafting to each propeller during a length of one hundred and eighty-six feet is rigid throughout. The brasses to these shafts are hollow, so that water may

circulate through them and keep the journals cool. The engines are provided with the ordinary slide valve without cut-offs, worked by the ordinary Stephenson link to cut off by lap at about half stroke. All the links upon each side are connected to a reversing gear operated by a pair of reversing engines, very conveniently arranged, so that one man may readily manage—slow down, stop, start, or reverse—the four engines attached to each propeller.

Forward of the boilers are two pumping engines and pumps for feeding the boilers, also two engines attached to each extremity of the same shaft, which extends across the ship, and upon which there is to be a large fan blower, drawing its supply of air down through bomb-proof gratings in the bomb-proof deck above, creating throughout the lower part of the vessel an excess of pressure. This is to cause in the furnaces of the boilers a powerful draft, independent of the height of the chimney, and throughout other parts a thorough ventilation.

Girders and Engine Frames.—In rear of the boilers, attached to the sides of the ship, are strong plate iron beams, running fore and aft, about fourteen feet up from the bottom. To these are attached five plate iron girder frames, extending across the ship, and placed one immediately forward of the forward boilers, and the other four between each pair of boilers. These fore and aft beams and athwartship girder frames are very strong, and well calculated to strengthen that part of the hull, besides being capable of supporting any superincumbent weight that may be brought upon them amidships. The engine frames are eight in number, formed of plate iron, each extending quite across the vessel, and firmly fastened to the sides, near the bottom, and at a height of about fourteen feet above it. These engine frames are also well calculated to support any required superincumbent weight which it may be desirable to place upon them amidships.

WORK REMAINING TO BE DONE.

It now remains to complete a small portion of the plating near the bow and stern; put in the beams and decks; attach a fore and aft keelson to the floor timbers amidships throughout the whole length of the vessel; make the flue connexions and chimney to the boilers; connect the engines, and add a few wanting pieces; put in floor plates to engine and fire rooms; make and attach the propeller shaft bearers to the outside of the vessel; supply the propellers; put in the required bulkheads; apply the armor, and the machinery for loading and working the guns, and to manufacture the guns themselves.

CHANGE OF PLANS.

Before describing the plans proposed for completing the vessel, it is proper to state that the original projector of the vessel was the late Robert L. Stevens, Esq., deceased; and that his brother, Edwin A. Stevens, Esq., who now proposes to complete it, has materially changed the plans from what appears to have been originally intended. Instead of the vertical sides above water, clothed with armor and pierced with gun ports, which seems to have been the design of Robert L. Stevens, the plans presented to us bear date of November, 1861, and resemble the inclined armor plated ships, the designs of which

have been patented in England by Captain Adderly Sleigh, in July, 1858, and by Mr. Josiah Jones, in November, 1859, with the important exception that in the English plans the inclined armor is pierced with gun ports, having an ordinary battery, with the guns and gunners protected overhead by a bomb-proof deck; whereas Mr. Stevens places his guns on the top of the upper deck, depending upon their immense size for their own protection, and for the protection of the gunners who aim and fire them, the training and loading of the guns to be accomplished by novel arrangements of steam machinery below the deck, yet to be elaborated; the guns to be trained to a certain position and depressed twenty degrees, to bring the bore in the same straight line with that of a steam cylinder below, to the piston head of which is attached a rammer and sponge.

DESCRIPTION AND PLANS PROPOSED FOR HER COMPLETION.

The present plans of Mr. Stevens for completing the battery, of which the following description is derived from information, with illustrative drawings, furnished upon call of the Board by him, contemplate an ordinary deck forward and abaft the machinery, fourteen feet from the bottom, beneath which will be coal, fresh and salt water tanks, and powder magazines, and upon which will be salt water tanks, provisions and shell rooms. At twenty-one feet from the bottom, a deck, which forward and abaft the machinery will be bomb-proof, by having a bottom layer of plate iron one-half inch thick; above this a layer of wooden planking six inches thick, covered with another layer of iron one inch thick. This deck is continued over the machinery, but in this part is of ordinary material and strength.

The Armor above water.—Over this latter part of the twenty-one feet deck is constructed the inclined armor, extending from three feet beyond the present side of the vessel to fourteen feet inboard, and seven feet high, giving an upper deck, upon which the guns are to be placed, of twenty-three feet wide amidships. This inclined armor is formed of plate iron in seven laminæ, six of which are one inch thick each, and the seventh three-quarters of an inch, making the thickness of iron six and three-quarter inches. Supporting this iron armor are iron beams eight inches deep, filled in between with locust. Under these again are locust planks six inches thick, making in all six and three-quarter inches of iron and fourteen inches of wood, placed at an angle of about twenty-seven degrees with the horizon. The forward and after ends of what may be termed the loading house, within this inclined armor, are inclosed by similar armor, inclined in a fore and aft direction; and it is forward and abaft of this that the twenty-one feet deck is bomb-proof.

The flat deck uniting the upper edges of this inclined armor is one hundred and twenty feet long, and is made bomb-proof by having, first, a layer of plate iron one-half inch thick beneath the beams, between which is laid wooden planking six inches thick, which again receives two layers of iron of three-quarters of an inch thickness each. Through this deck the heated gases from the boilers rise between the bars of a bomb-proof grating, an ordinary smoke pipe rising above the

grating, which is to be removed, if desired, on going into action. Forward of the inclined armor upon the twenty-one feet bomb-proof deck are the capstan for weighing the anchors and the quarters for the men. Abaft the armor, upon the same deck, are the quarters for the officers, cabin, ward room and steerages. This bomb-proof deck and the inclined sides of the armor are covered with a light deck of two inch planking, supported by wooden beams five inches square and two feet apart, placed at such a height that its upper side is flush with the bomb-proof platform upon which the guns rest. The edges of this light deck are supported by light iron sides one-quarter of an inch thick, running up vertically from the outboard edge of the armor.

The Armor below water.—From the twenty-one feet line downwards six feet, the sides of the vessel are protected by armor composed, first of oak timbers placed next to the iron plating of the ship, having a thickness at its upper edge of three feet, with a triangular cross-section, such that its outboard side forms a continuation of the slanting side of the vessel, which, up to this point of meeting the armor, has an angle with the perpendicular of about twenty-six degrees. From the twenty-one feet line down to the outer side of this oaken armor extends to a depth of three feet, iron plating two inches thick, within which, down to a depth of two feet, is iron plating one and one-half inches thick, so that the side armor of the vessel, extending throughout its entire length, consists of iron three and a half inches thick to a depth of two feet, and two inches thick for one foot further down, backed by solid oak three feet thick at the upper edge amidships, the thickness gradually lessening as it descends, until at six feet depth the iron sides of the vessel itself are depended upon. As the vessel will draw twenty-one feet when loaded with stores, ammunition, and coal, the upper edge of this side armor will be on a level with the surface of the water. Near the bow and stern the oaken part of the side armor is not so thick as amidships, being two feet thick at its upper edge at forty feet from the bow and sixty feet from the stern.

Masts.—There are to be two short masts of hollow plated iron, arranged with hinges near the deck, similar to those in the English steamer *Great Western*, so that they may be lowered to the deck when going into action.

The Armament.—The armament proposed consists of five 15-inch Rodman guns, weighing with their carriages 60,000 pounds each, and two 10-inch rifled guns, weighing with their carriages 40,000 pounds each. These, as before stated, are placed upon the extreme upper deck, over the engines and boilers. The deck upon which they rest is supported by columns of wrought iron, which rest upon the engine frames and the strong plate iron girders before described as rising from the bottom and sides of the ship between the boilers. These guns are mounted upon carriages of a novel construction, so arranged that they may be trained to any point in the horizon by simply revolving a vertical shaft, which passes down through the deck and is attached to steam machinery below. The upper end of the shaft terminates in a T head or horizontal cross bar, whose length is equal to the interior

breadth of the gun carriages. Between this head, or cross bar, and the interior ends of the carriage are india rubber springs forty inches long, and when the gun is fired it is expected, from experiments which have been tried with a ten-inch gun of 10,000 pounds weight, and a charge of powder of eighteen and three-quarters pounds, throwing solid shot weighing 124 pounds, and calculations deduced from them, that the gun will recoil at a maximum twenty inches, or one-half the length of the springs, and that the reaction of these springs will restore the gun to the position which it occupied before it was fired—similar springs upon the opposite side of the cross bar receiving the shock caused by their reaction.

It is expected there will be one man on this upper deck in time of action to each gun, who will direct by appropriate signals, or indicators, its training to those below, and aim and fire it. It is considered by Mr. Stevens that guns of this size will not be injured even when struck by the enemy's shot. This, however, is to be the subject of experiment before the completion of the vessel, and if an opposite result should be arrived at from these trials, they are to be protected by wrought iron armor, in a manner about which he has no doubt, and that when a gunner sees a shot coming he can stand on the friendly side of the gun for protection, the carriage underneath the gun being made shot-proof by wrought iron armor plates. When the gun is to be loaded, the gunner on deck causes it to be trained to the loading position, which in each case brings the gun nearly in line with the keel; he then depresses it about twenty degrees, bringing its muzzle opposite a bomb-proof opening in the deck corresponding in size and direction to the bore of the gun. Below the deck is a long slender steam cylinder, having upon the outer and upper extremity of its piston rod a compound sponge and rammer. The attendant admits steam to either side of this piston as required and sponges out the gun; then the ammunition, being placed in a position near the muzzle, is rammed home by the steam rammer, after which it is elevated by the gunner above, trained upon the enemy and fired.

PROTECTION BY PARTIAL SINKING.

When the vessel prepares for action with the enemy, she is settled to a greater than ordinary draft by the admission of salt water, as follows:

"Water to be admitted into tanks below two feet line,	213 tons.
" " interstices of the coal, .	350 "
Water to be pumped up into tanks on deck, . .	537 "
Total water for settling, ...	1100 tons."

Only one-half of this water is required when the ship is already down to her deep load line, but the whole amount is provided for, so that she may be brought to the fighting draft when her coal and provisions are nearly out. This settling of the vessel is for the purpose of adding to the armor plates the protection secured by water against shot.

TO BE LIGHTED WITH GAS.

The vessel is to be lighted with gas generated on board by placing the retort in one of the boiler furnaces, in a manner similar to that now in use on board the ferry boat *Hoboken*.

FLOATATION AND STABILITY.

To determine the floatation and stability of the ship, we have carefully computed the weight of the vessel and all that it is expected to put in it, with their centre of gravity, the displacement of the vessel, the centre of gravity of displacement, and the height of the metacentre. The displacement of the side armor is included in computing that of the vessel, and the extra beam it gives the ship was considered in estimating the height of the metacentre. The weights include those of four hundred men and officers, provisions for three months, ten thousand gallons of fresh water in tanks, one hundred and twenty-five rounds of shot and shell, one hundred and fifty rounds of powder, and eight hundred tons of coal. The result of the calculation is as follows:—

DRAFT OF WATER, TWENTY-ONE FEET.

Displacement in cubic feet,		188,248
Displacement in tons of 35 cubic feet each,	tons 5,378·5	
Add for iron plating,	18·5	
Total displacement,		5,397·0
Area of midship sections,	sq. ft.	817·0
Arch of load water line,		13,788 0
Displacement per inch at load line,	tons 32·8	
Weight of loaded ship by computation,	5,280·0	
Add for contingent,	117·0	
Total weight provided for,		3,397·0
Depth of centre of gravity of loaded ship, below load water line,		ft. 5·49
" " " displacement, " " "		8 657
Height of metacentre above centre of gravity of displacement,		10·535

Data for Judging of the Form of the Vessel.

Midship Section.		Areas of Immersion Section.	
Height from bottom.	Breadth.	Distances from bow.	Areas.
Feet.	Feet.	Feet.	Square feet.
21	51·0	20	51·0
20	49·8	40	136·8
19	48·8	60	240·0
18	47·8	80	250·6
17	46·8	100	466·0
16	45·8	120	584·6
15	44·8	140	783·0
14	43·8	160	748·8
13	42·8	180	799·8
12	41·8	200	817·6
11	40·8	220	803·4
10	39·8	240	776·4
9	38·8	260	704·0
8	37·8	280	617·8
7	36·8	300	516·4
6	35 8	320	422·4
5	35·0	340	323·2
4	33·8	360	228·2
3	32 2	380	120·6
2	28·0	400	33·8
1	17·6	—	—

Having thus described the vessel and its appurtenances, it remains to state the cost, time required for its completion, and the expediency thereof.

COST.

The total cost of the vessel complete (except stores) is estimated to be, ...	$ 1,283,294·00
Of this amount there has already been paid by the government,	500,000·00
Leaving yet to be provided for, . . .	783,294·00
Of this latter sum Mr. Stevens states that he has expended from his own resources towards the completion of the ship,	228,435·87
Leaving as a representative of the amount of work yet to be done, ...	554,858·13

TIME REQUIRED FOR COMPLETION.

The time required for completing the entire structure, ready for service, is estimated by Mr. Stevens at four months from the date of recommencing the work.

EXPEDIENCY OF COMPLETING HER.

The expediency of incurring the above expense in producing such a vessel as described, is best determined by examining in detail the many novel characteristics she would possess.

She differs from the ordinary war vessels with which we are acquainted. First, in having long slender ends. Second, in employing two independent propellers with several engines attached to each. Third, in depending entirely upon a fan blower for the ventilation of the lower part of the vessel when in action. Fourth, in employing a heavier armament than has ever yet been put afloat, and training and loading these heavy guns by steam machinery below the deck, manipulated by persons who do not see the guns. Fifth, in having the guns exposed to the direct fire of the enemy upon the top of, instead of within, an iron-clad vessel. Sixth, in settling the vessel when going into action, and in several other respects which will develop themselves in the course of this report.

1. The great length of this vessel, compared with the transverse strength, strikes a nautical man at once, and a careful investigation clearly indicates that it would be the height of professional imprudence to send such a vessel to sea. The action of the waves would cause her to writhe and twist to an extent that would soon open the seams of her light iron sides. Her use, if completed, would therefore be confined to the defence of the harbor; her inconvenient length and her draft of water, which could not be reduced to much less than nineteen feet, even for this service, when fully equipped, would militate against her usefulness to a certain extent.

2. The employment of two independent propellers instead of one would appear to possess great advantages in effecting great rapidity of manœuvres when in the presence of the enemy, and would be all the more useful to her for being compelled to confine her operations to the defence of the harbor, the channels of which would be comparatively restricted by her great length and draft of water.

The application of more than two engines to one propeller shaft, arranged, as in the case of this vessel, to occupy a considerable por-

tion of its length, has its advantages and disadvantages. It no doubt distributes over a greater area the reactive strains which the engines bring upon the vessel when they are in operation, but it also adds to the first cost of the machinery, the space occupied, and the labor of attendance.

3. In ventilating the lower part of the vessel by artificial means during action, it must not be forgotten that fresh air is a constant necessity to human life, and to maintain it in this vessel there must be always steam up and the fan in operation.

4. One of the most important features of the vessel is that of using very heavy guns. The five 15-inch smooth bore and the two 10-inch rifle guns throw fifty per cent. greater weight of metal, per broadside, than our heaviest forty-four gun steam frigates, armed with heavy Dahlgren guns.

5. It being a part of the design of this vessel that these guns shall be large enough for their own protection against the shot of the enemy, it would be well to examine the question of how large must be the mass of cast iron to secure it against injury from such a source. The 15-inch Rodman gun, now at Fortress Monroe, is four feet diameter at the breech, and two feet one inch at the muzzle, is fifteen feet ten inches long, and weighs 49,100 pounds. Experiments were tried at Woolwich, in England, in September, 1857, by firing from a sixty-eight pounder, ninety-five hundred weight gun, with a charge of sixteen pounds of powder, four wrought iron shot, at a distance of six hundred yards, and cast iron shot at a distance of four hundred yards, at a target composed of three cast iron blocks, each eight feet long, two feet high, and two and a half feet thick—average weight of each block eight tons. They were placed one above another, a groove being cast on the upper surface of the upper block, three inches deep by fourteen inches wide, to receive a corresponding projection on the under surface of the block above it. This target was supported in rear by a rectangular mass, consisting of six heavy blocks of granite, each block $4\frac{1}{2} \times 3 \times 2$ feet, leaving four and a half feet of the centre of the target unsupported. This wall of cast iron was struck ten times and entirely destroyed. (*Vide* "Naval Gunnery," by General Sir Howard Douglas, fifth edition, pp. 404 and 405.)

There is no doubt in our minds that the metal of the Rodman gun is much stronger than that of the cast iron blocks forming the target above described—(for reason of which see "Notes on Sea Coast Defence," by Major Barnard, U. S. A., p. 36)—but still the results are so remarkable that until further experiments are tried, bearing more immediately upon the case, we cannot consider any cast iron gun as proof against the assaults of heavy ordnance when exposed, as these are, to the direct aim of the enemy, by being placed upon the extreme upper deck of the vessel, with neither bulwarks nor railing to screen them from view, and with the necessity of being trained to a position nearly in line with the keel every time they are loaded. Mr. Stevens has stated to the board that, if experiment shall establish that the guns

are not thus, in themselves, their own protection from the effect of shot, he is prepared to clothe them with angular wrought iron armor, which he considers will be effective.

6. The project of settling the vessel down two feet beyond her deep load draft, when preparing her for action, by admitting water from the sea to different compartments of the vessel, and, after the battle is over, elevating her again to the normal draft, by pumping the water out, is so remarkable a departure from all previous naval practice, that the board has given the subject considerable attention in its various bearings upon practical operations.

First, with regard to the compartments within the vessels which are to receive this water. The statement of Mr. Stevens upon this point is that 213 tons are to be admitted into tanks below two feet line. Now, these tanks are neither more nor less than the spaces between the floor timbers of the ship, or, in other words, the bilge, a part of the vessel that every prudent commander keeps as free from water as possible; but, aside from this, it is well known that the bilge water, of steamers especially, is constantly liable to choke the pumps, on account of the debris contained in it, so much so that in all good steamships several different pumps are arranged to pump from the bilge, not so much with the expectation that they will all be required at once, as that some of them may certainly be in good pumping order.

The statement of Mr. Stevens further is, that 350 tons are to be put into the interstices of the coal. This we regard as highly impracticable. To say nothing of the impossibility of getting coal from the bunkers while they are full of water, the difficulty of again pumping the water out, filled as it would be with small particles and dust of the coal, entirely precludes, in our opinion, the use of that part of the ship for such a purpose. Mr. Stevens proposes to use a kind of pump for this purpose which, it would appear, has worked very well for similar purposes in civil engineering. Its application to vessels of war, however, is novel, and it is liable therefore to the objection of all untried projects.

Secondly, the quarters for the men and officers are upon the bomb-proof deck, which is about on a level with the surface of the water at the ordinary deep load draft, and would therefore be about two feet below it when the vessel was in action. The sides above this deck are made of thin iron, easily perforated by the lightest artillery, so that a heavy shot forward or abaft the loading house, making a large perforation near the water line, would flood this entire deck, adding immediately an enormous weight to the vessel for which no provision has been made. But one consequence could follow such a disaster—the ship would sink.

From these considerations, it is very clear to us that whatever theoretical excellence there may be in partially sinking the vessel for her better protection in time of action with an enemy, the plans here proposed for putting the project into execution are entirely impracticable, and would never be resorted to by any prudent commander.

HULL NOT SUFFICIENTLY STRONG TO SUPPORT THE ARMOR.

The sides of the vessel above the fourteen feet line have no extra support beyond those usually applied to a merchant steamer; and yet in the proposed plan they are to sustain the weight of the side armor and the upright side, which rises from its outer edge, which amount to 350 tons; added to this is one-half the upper inclined armor, which protects the sides of the loading house under the guns, making together 800 tons to be carried by the upper edges of these light overhanging sides, without any extra provisions being made to carry any extra weight whatever. This strikes us as a remarkable defect, which it would be difficult to remedy in any manner, even if the buoyancy was sufficient to carry the added weight of such remedies.

EFFICIENCY OF THE ARMOR.

Aside from the above defect, there can be little doubt but that the loading house is efficiently protected against the heaviest ordnance now afloat in any part of the world. Above water, the armor is fifty per cent. thicker than that which is applied to the French and English iron-clad vessels, and instead of being placed at right angles to the line of direct fire, is at an acute angle with it—an immense advantage in attaining impregnability.

The side armor, where it joins this upper loading house portion, is well calculated to protect the vessel, if she be kept at all times down to the loaded draft; but forward of this during a length of 96 feet, and abaft for a length of 136 feet, we regard it as very deficient in having the iron plating placed in an inclined position, while the oaken backing only supports it horizontally. Although the shot comes in a horizontal direction, the pressure upon the plating is at right angles to its surface, and, therefore, partially upward; the result would be, that the iron would give way for want of proper support in the direction where the support was needed. This would not admit the first shot that strikes this armor to the interior of the vessel below the bomb-proof deck, but there would be very little protection against the next shot which struck near the same place.

POWER AND SPEED OF THE VESSEL.

In designing the power of the vessel, and determining the amount of steam power which should be placed in her, great sacrifices have been made to attain the very important desideratum in a war steamer —high speed.

It is claimed by Mr. Stevens that her machinery is capable of exerting a power of 8600 horses, and that this will give her a speed of twenty sea miles per hour—greater, it is believed, than that of any war steamer in the world.

Although, for reasons already stated, the sphere of action of the vessel would necessarily be confined to the defence of the harbor, where great speed for any distance would not be required, but where, nevertheless, a high speed, even for a very short distance, might,

when manœuvring against an enemy, be of immense advantage. Indeed, the great power claimed would be of very great advantage simply when applied to the propellers in opposite directions for the purpose of turning around quickly.

To obtain this power of 8600 horses, it is proposed to carry within the boilers a pressure of fifty pounds per square inch, and to run the engines seventy-five revolutions per minute.

With the above pressure and revolutions given, the power would be obtained; but prudent engineers would not place the limit of maximum pressure to be at any time carried upon boilers of this description at higher than twenty-five pounds per square inch. Not the slightest objection is urged against the use of steam of as high a pressure as fifty pounds per square inch, however, even when, as in this case, salt water is to be used in the boilers, because, as far as the latter condition could be brought as an objection, it is replied that such a pressure and the resulting power would only be required for a short time at probably great intervals; but if high pressure is desired, boilers strong enough to carry it with perfect safety should always be provided.

With regard to running these engines at a speed of seventy-five revolutions per minute, it will be remembered that each system of crank-shafts has eight bearings, or one at each engine frame, and that, although the part which receives the power of each engine has been forged separately from the others, they are coupled rigidly together, giving what is virtually a single rigid crank-shaft of fifty-three feet in length, with eight bearings. Each of these bearings are so arranged that it may be turned as on a pivot, both in a horizontal and a vertical direction, which would be a very useful quality if there were but two bearings, as then the axis of each could always point towards the other, no matter in what direction the cramping of the ship would move them. But it is clear that where there are more than two, each bearing must remain in a fixed position, or their axis will not be in a straight line. But these bearings, extended over so great a length of the vessel, would, when the full power of the engines were upon them, depart materially from the straight line which perhaps existed when in a state of rest, and the result would be that the journals of the shafts would be cramped in their bearings to an extent that would cause them to heat beyond the power of water to keep them cool, when running at a higher speed than forty revolutions per minute.

There would be little or no difficulty, however, in overcoming this defect by substituting movable for the rigid couplings between the crank-shafts of each separate engine. With this modification there would be no difficulty, as far as the machinery was concerned, in running them eighty revolutions per minute. The power of 8600 horses would, therefore, be modified as follows:—

The mean effective pressure per square inch upon the piston, when carrying fifty pounds of steam in the boilers, was fifty pounds, in the calculations of Mr. Stevens. When carrying twenty-five pounds in

the boilers, this would be twenty-nine pounds, which would therefore give $8600 \times \frac{80 \times 29}{75 \times 50} = 5320$ horses power. Even this allowance gives the boilers credit for the excellent performance of producing one horse power for every five and one-fourth square feet of fire surface.

If, therefore, 8600 horses power would produce a speed of twenty miles an hour, that of 5320 horses power would give

$$\sqrt[3]{20^3 \times \frac{5320}{8600}} = 17 \text{ miles, nearly.}$$

With regard to having allowed in this modification of the power an increased number of revolutions with a lessened pressure, it may be proper to state that the propellers have not yet been designed, and it will only be necessary to give a less pitch to them than would have been required with the greater pressure.

INABILITY TO FIRE IN A LINE WITH THE KEEL.

One of the important features claimed for this vessel is, that each of her guns may sweep the horizon without changing the direction of the ship; that she would advance upon the foe with her unrivalled speed, firing her enormous guns in a direct line with her keel as she approached. Similarly, that if chased by a superior force, she could retire rapidly at the same time that nearly her whole armament was sending back its destructive shot and shell.

The armament, considered by itself, is certainly as well arranged for firing several guns in a line with the keel as in any other direction; but it will be remembered that, forward of the guns, forming the quarters for the men, and abaft them, forming quarters for the officers, is a light wooden deck made of two inch planking, supported by wooden beams, five inches square, placed two feet apart. Every artillerist knows what would become of this deck upon firing the first 410 lb. shell across it a distance of 120 feet. It would be demolished, and so also would the same deck where it extends over the inclined armor, when the guns were fired *en* broadside. But here it would not be of so much importance; the deck and the light sides which support it could be dispensed with, and might well be left out in the construction of the vessel; but the deck forward and abaft are necessities, and would be destroyed by any prudent commander only when driven to the last resort. She would be compelled, therefore, to lay her broadside to the enemy, exposing to his fire the full length of each gun every time it was placed in position for loading.

CONCLUSION.

In conclusion, we beg leave to express our highest appreciation of the objects Mr. Stevens has apparently had in view when planning this vessel—the most powerful battery, the highest speed, and the most thorough protection of any vessel yet produced—and our regret that the plans of the vessel as presented to us would not, in our

opinion, accomplish fully and completely the ends proposed. We look with the deepest interest upon every addition to the efficiency of our navy, of whatever character, and gladly hail every improvement made to any department of it; but at the same time we cannot recommend the expenditure of important sums of money upon projects of more than doubtful success when put into practical execution, and, therefore, we do not deem it expedient to complete this vessel upon the plans proposed.

All of which is submitted by, very respectfully, your obedient servants,

S. H. STRINGHAM, President of the Board.
WM. INMAN, Commodore.
THOS. A. DORNIN, Captain U. S. N.
ALBAN C. STIMERS, Chief Engineer U. S. N.

Hon. GIDEON WELLES, Secretary of the Navy, Washington, D. C.

Attached to the foregoing is the

REPORT OF PROF. HENRY.

I readily concur with the other members of the board of Commissioners in the statement given in the foregoing report, as to the condition of the vessel as it now is, and in reference to the general account of the plan proposed by Mr. Stevens for finishing it, as well as in the statement given as to the amount of money and length of time which would be required to complete the vessel in accordance with the plans proposed. I also highly appreciate the objects intended by Mr. Stevens, and the laudable endeavors which he has exhibited to improve the defences of our harbors. But I cannot, with my present knowledge, concur in the decided opinion expressed by the other members of the board in regard to the expediency of finishing the vessel.

If I rightly understand the design of Mr. Stevens, it is not to confine the operations of the battery to inner harbors, but also to employ it in outer harbors, and especially in the waters immediately beyond, and therefore the important problem to be solved is, whether the vessel can be finished in conformity with the general plan proposed so as to withstand the waves of the sea to which she may thus be subjected. All the material objections which have been brought against the plans of Mr. Stevens are, in my opinion, merged in this one question; and from a due consideration of all the facts which have thus far been presented to me, I am not convinced that it cannot be solved. On the contrary, it appears to me that, although the vessel may not be a convenient or safe ship for long voyages, she might be made of sufficient strength to withstand the exposure to which she would be subjected, and to efficiently perform the service required. If requested to do so, I will furnish the reasons for this opinion at some future time.

Respectfully submitted,

JOSEPH HENRY.

Extract from a Paper on the Concrete used in the late Extension of the London Docks. Read before the Royal Scottish Society of Arts. By GEORGE ROBERTSON, C. E., F. R. S. E.

From the Lond. Civ. Eng. and Arch. Journal, January, 1862.

The gravel found on the works was not always so free from clay as could be wished. It had often to be screened, to reduce the quantity of sand to the proportions necessary to form a good mortar with the lime used. Concrete is really minute rubble work of pebbles set in mortar, more or less perfect according to the care taken in mixing the ingredients. In theoretically perfect concrete, the mortar should be made, *first*, to insure a perfect matrix for the pebbles to be embedded in; but this is not the usual practice in this country. The great mass of the concrete was composed of one measure of lias lime to six measures of gravel, both being measured by boxes, and not by guess-work. Sometimes, however, a layer of gravel was spread out a foot thick, and then lime laid over it for a depth of two inches. This is not so good a way of measuring as by boxes, because the lime falls between the pebbles, and the concrete is richer in lime than the engineer intends, which is no advantage to the work, and is, of course, a loss to the contractor. When the ballast was moderately dry, 12 cubic yards of gravel and 2 cubic yards of lime made 11 cubic yards of concrete, mixed and deposited. The shrinkage of the dry materials was then 22 per cent.; but if the ballast happened to be very dry, the shrinkage was more, and the same quantities made only 10 cubic yards.

A cubic yard of concrete requires about 38 gallons of water to bring the dry materials to the requisite state of fluidity. Of this quantity nearly 8 gallons enter into chemical combination with the oxide of calcium in the lias, and 30 gallons are either absorbed mechanically by the pores of the lime, retained by capillary attraction between the grains of sand, or lost by evaporation. After the concrete has been mixed and deposited, a gradual expansion takes place from the chemical action of the lime slaking; the less of this swelling, however, the better, as it disturbs the setting of the mortar round the pebbles, and causes friability in concrete. Whenever concrete is made with quick-lime (as it usually is) there must be a certain amount of friability from this cause; and, therefore, when it is important to have no swelling, as in blocks of concrete which have to be lifted, recourse must be had to slaked lime, or else to cement, which contracts rather than expands in setting. In the one case the concrete is long in hardening, having more moisture in it than the lime can absorb; and in the use of cement more expense is incurred. Portland cement is, however, not so expensive as might at first appear from the cement being double the price of lime, because the proportion to the ballast may be considerably reduced.

Some experiments on the expansion of concrete proved to me that it varies a little with the season of the year. In hot summer weather the expansion of a cubic foot in twenty-four hours after mixing was as much as $\frac{1}{30}$th of its bulk, usually $\frac{1}{32}$d; but in frosty weather it rarely

exceeded $\frac{1}{48}$th. The force exerted in the expansion was always sufficient to burst the box in which the concrete had been deposited; the amount might even be measured by the distance the nails were drawn out. Whenever the expansion exceeded $\frac{1}{30}$th of the bulk, I considered the concrete too rich in lime, and that there was more than would, when slaked, fill up the interstices of the sand and flints, and coat each grain with a thin pellicle of lime. More than this is not required, for too thick a coating of lime causes weakness, and not strength.

The gravel and lime were mixed together on a platform of planks, and were turned over twice in the dry state, and twice with water gradually added. The concrete was then wheeled in barrows, and shot into the required place from planks a few feet above. The idea that concrete should be thrown in from a great height is erroneous, for it then falls with too great force, and disturbs the setting of the mass below, causing unnecessary friability. This was particularly noticeable in the deep pits for the counterforts of the north wall of the basin, where the concrete had unavoidably to be thrown from a height of 30 feet. The force of the blow set the whole mass in motion for some feet down, even after setting had fairly commenced. Lias concrete sets slowly, and in this case it was impossible to wait long enough for each layer to become perfectly hard before depositing another, as the wall had to be built with the utmost expedition, as will be seen hereafter. Anything gained in density by a fall of more than 6 feet is more than counterbalanced by the disturbances to the mass below. The grand rule in concrete is, not to disturb it after setting has once commenced. Wherever it is necessary to shovel it into corners, or pack it between stones, it should be done at once, and the concrete not touched again. The swelling of the lime during slaking causes enough natural friability, without increasing it by after-disturbance.

By arrangement in the contract with Messrs. W. Cubitt & Co., the contractors for the greater portion of the permanent work, ground lias lime was sold to them for 10*d.* per bushel; and at this price the cost of making a cubic yard of concrete was as follows.—

	s.	*d.*
3¾ bushels of lime at 10*d.*,	3	1½
Loading, waste, and bags for ditto,	0	3
Getting gravel,	0	6
Wheeling do. (say 5 runs),	0	4
Screening and selecting ditto,	0	3
Mixing and depositing,	1	1
Platforms,	0	1½
Total cost per cubic yard equal	5	8

As the quantity of gravel fit for concrete was uncertain before the ground was opened up, for the sake of simplicity the whole excavation had been estimated as barged away; and for each cubic yard of gravel used as concrete, a certain deduction was made in the monthly payments.

The supply of water for mixing the concrete was obtained from pipes laid down to the various parts of the works, either from the street

mains or from the launder of the pumping engine. In mixing large quantities the expense of laying pipes is soon saved.

The Application—Concrete was applied on the works of the London Dock extension in several ways:—1, In foundationss for masonry or brickwork, as a means of spreading the weight over a large surface; 2, As the cheapest method of reaching a good foundation in the clay or gravel, whether for walls or piers of warehouses, &c.; 3, In the dock walls themselves, wherever the concrete would not be exposed to the alternate action of wind and water; 4, As counterforts or buttresses, on which nothing was to be afterwards built, but where weight was wanted.

In all these cases it is to be noticed that it was applied as a mass, in the monolithic form, which is the true use and value of concrete. Whenever it is moulded into separate blocks, to be afterwards set in proximity to each other, concrete becomes an inferior substitute for stone, although often an economical and useful one.

The whole of the side walls of the two locks rested upon a bed of concrete, of a thickness varying very much with the level of the clay, from 3 feet to 6 inches. The invert of the lock chambers was laid on concrete, and the spandrils of the arch filled up with it. The high chimney of the pumping-engine house stood on a square of concrete of considerable thickness, the pumping engine itself resting on beech piling. As this chimney was very close both to the pumping well (18 feet in diameter) and to the excavation for the lower dock, there was some risk of unequal settlement. A plumb-bob was therefore left suspended in the chimney, which at once would give warning of any inclination either way. Some time after the chimney was built the plumb-bob showed that the shaft had inclined several inches towards the excavation. A quantity of limestone was at once stacked round the base of the chimney on the opposite side, which brought the shaft back to the perpendicular.

Concrete was used as the cheapest means of reaching the clay, in the foundations for the lattice swing-bridges over the locks; the bridge pits resting on arches, the piers of which were of concrete up to a certain height. Columns of concrete were built up likewise in the proper places, upon which cranes and capstans might be placed when required. The whole of the walls and iron columns of the new warehouse rested on trenches of concrete about 8 ft. wide, and averaging perhaps 8 ft. in thickness, from the top of the natural gravel to the level of 17 feet below high water. As the concrete here was not to be exposed to the direct action of water, it was made of Dorking or grey stone lime, in the proportion of 1 of ground lime to 8 of ballast. This lime carries more sand than lias; is but feebly hydraulic, and, indeed, not permanently so at all. It is the lime used in London for building purposes, and by some engineers even in dock work when mixed with pozzuolana.

By far the largest quantity of the gravel found in the excavation was used up in the construction of the walls of the basin, in which everything below the level of 17 feet from high water was of concrete,

faced with 2 feet of Kentish rag-stone, to protect the surface from the disintegrating effects of water. At this low level there was no fear of vessels rubbing against the rough faces of the rag-stone. The general type of the basin walls was much the same as that of the West India Junction Dock walls, where Mr. Rendel used concrete of 1 part of Portland cement to 9 parts of gravel.

The concrete portion of the basin walls was 17 ft. 6 ins. broad at the bottom, and 11 ft. 6 ins. at the top, the face being curved at first to a radius of 11 ft., and then carried up with a batter to the bottom of the brickwork, which was perpendicular. Whenever concrete is faced with rag-stone, it should be built with a batter, and the layers slightly inclining away from the face. All danger of the wall bulging out, or of the face-work peeling off, is then avoided. The Kentish rag-stone facing was hammer-dressed on the joints for a specified distance in, and care was taken to have at intervals long wedge-shaped stones, with the broad end inwards, tailing well into the concrete, which was carefully packed between the joints when first deposited. About two feet high of face-work was first set, and then the concrete deposited in two layers of about one foot thick each. The first layer was allowed to harden for at least 24 hours before the second was deposited, and they were always arranged so as to break joint. A layer of concrete does not thoroughly incorporate with a previous one unless the meeting surfaces be kept rough, and free from sand. But, by sweeping off all sand, and, if necessary, picking the face in furrows, and by breaking joint with the layers, all danger is avoided of either a vertical or horizontal run of water through a mass of concrete. The brickwork of the upper half of the wall, with its counterforts, was not laid on landings, as in the lock walls, but was for three feet set in superior mortar, with hoop-iron bond every three or four courses.

Steel-Surfaced Rails.

From the London Mining Journal, No. 1371.

We learn that the use of Mr. Dodd's steel-surfaced rails, to which we have upon several previous occasions referred, is gradually becoming more extended, through the great durability which they are found to possess rendering their application very economic. The mode adopted for steeling the rails is so simple, that there is little addition to the cost, yet so great is the effect produced upon the rail that it will last at least thrice as long as an ordinary rail, and it is estimated that the saving upon each 100 miles laid is equal to nearly £120,000. We have already mentioned several of the principal lines upon which the rails have been tried, and more recently it has been decided to employ them upon several Scotch Railways, and "after great consideration and examination of rails which have undergone Dodd's patent process for steeling the surfaces," Mr. John Fowler has ordered 1200 tons for the Metropolitan Railway. The case-hardening furnace is easily worked, and in three days the surface of the rail for the depth of $\frac{1}{8}$-inch, can be converted into hard and durable steel.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Alloys of Cadmium. By B. Wood, M. D.

(Continued from vol. xli. p. 29.)*

After so long an intermission, due to circumstances which it would not benefit Science to enumerate, we come to speak of some of the combinations of cadmium with the softer or more fusible metals.

To represent their principal qualities to the eye at a glance, and to facilitate description, I have prepared the following tables, in which several well known metals are arranged as standards of comparison. On these points a few remarks may be required by way of explanation.

SCALE OF HARDNESS.

Different methods of determining the hardness of metals have been adopted, none of which appear to be altogether free from objection. The most accurate mode, by means of a graduated punch worked by lever and weight, adopted by Messrs. Calvert and Johnson, is quite tedious, and the machinery too complicated for common use. Ordinarily the main object of examining a metal in respect to this quality is, not so much to determine the hardness of its particles as indicated by the common method of scratching the surface of another with it, or *vice versa*, nor to ascertain its interstitial compactness as by penetrating its substance by means of a pointed instrument under pressure of a given weight, but rather to find out the relative amount of force it, as a mass of a determinate form, will sustain without yielding or giving way, as compared with other metals in like form and condition. That is, we wish to know its state of coherence *as a body*, subjected to the test of pressure, in comparison with similar specimens of other metals, so as to determine our choice for a particular use. A piece of grindstone will *scratch* iron, though iron is much the harder. A substance may be penetrated in the direction of cleavage, or along the plane of crystallization, with ease, when, at other points, it would resist a greater force. The same may be inferred of those metals that are crystalline, or lamellar, in structure.

Nor is it the absolute hardness of a specimen that is the object of practical concern, but simply to know which of any two or more metals, relatively considered, will, in respect to this quality, best answer the end.

The mode adopted for ascertaining the relative hardness of metals represented by the table, is simple and convenient, and affords a good practical test for common use. Specimens of the metals to be examined are cast in the form of triangular bars, measuring at the sides about a quarter of an inch. These being applied edge to edge and placed under pressure in a vice, the relative hardness of any two

* Errata.—Vol. xl. p. 113, four lines from bottom, for "sooner" *read* "later."
Vol. xl. p. 115, seventeen lines from bottom, after "former," a comma in place of the semicolon.
Vol. xli. p. 26, twenty-five lines from bottom, for "as" *read* "contrary to what."
" p. 27, two lines " after "silver" insert "20 gold."

pieces is determined by the relative amount of indentation received by them. If the one be deeply indented or cut, and the other not sensibly or but slightly notched, the former is reckoned at least one degree the harder—and if no impression be made upon it, it may claim a still higher figure in the scale; its precise place being ascertained by further comparison. If both specimens be strongly indented, although differing in degree, and the indentation of the one be no more than half that of the other, they rank in the same class: or if the difference be still greater, the one may take an intermediate place, or be ranked in the class to which it is most nearly allied, with the sign + or — attached, according to circumstances; or it may be designated by the numbers representing both classes. Thus an alloy of one part of tin and nine parts of antimony being deeply indented by the metals in class 5, while it also reacts upon them strongly, would, to be definite, be represented by — 5. An alloy composed of lead and bismuth, each one part, and tin two parts, being nearly midway in hardness between the classes 4 and 5, may be represented by 4—5; or, for greater precision, by the use of a decimal, 4·5. These remarks apply also to the designation of other qualities.

The metals in the scale are so arranged that to this test each will be found to cut or divide the one next above it, and to be divided by that next below, without perceptible reaction in either case.

A mould for forming such bars (which, for the want of a better, could be carved out, with a chisel, from a slab of soapstone,) may be modeled so as to obtain, at the same casting, specimens for determining the qualities of flexibility and malleability, as below indicated.

FLEXIBILITY.

All metals possess some degree of flexibility. A brittle metal admits of considerable flexion when in thin plates, and the amount will depend upon the thickness of the point operated upon. By bending similar bars of different metals, at a constricted point (so as to prevent yielding at other parts), and noting the number of degrees described before breaking, we arrive at an approximation in this particular. The metals represented by the table, flexed at a point one line in thickness, break as follows—reckoning the angle of breakage from that at which the piece cracks or *begins* to separate:—Class 1, at 5° or less; class 2, over 5° and under 20°; class 3, over 20° and under 45°; class 4, over 45° and under 90°; class 5, 90° and upwards. A metal that may be uniformly bent the thickness named to a right angle may be accounted perfectly flexible. Beyond this the method is unsatisfactory, as the more flexible metals break gradually, sometimes thinning down to a mere thread before separating. Nor is it altogether satisfactory in other cases; and to assist our determinations, we have to take into account not only the angle of flexure, but the mode of fracture, or rather the manner of breaking, as the word "fracture" is usually applied to designate the *appearance* of broken surfaces. Some flexible metals after a certain amount of flexion break short, as though rendered brittle by the process, like cadmium; others, as tin, separate by gradual attenuation. Of the more brittle kinds, some at a certain an-

gle break through abruptly; others at the same point merely crack upon the surface of tensure, separating more and more as the strain is continued, and dividing completely only after a wide sweep. In short, some *tear*, some *break*, others *snap*. Again, some alloys will snap under a sudden strain that admit of considerable flexion if the force be gradually applied. A rigid description would express all these conditions, with terms appropriate to each. Moreover, in order to completeness in regard to this quality, independently considered, not only the amount of flexion, but also the force required to produce it, should be measured: but the *hardness* of the metals will afford some criterion in this respect. I have thought it not out of place, or unimportant, to thus indicate what remains to be done.

MALLEABILITY.

The metals are classified in the scale according to the reduction in thickness they will bear under the hammer, without breaking, whether through the centre or at the margin. Specimens, cast in the form of a bullet three lines in diameter, being subjected to this test, and the amount of reduction measured by means of a pair of callipers, it was found that the metals ranked in class 1 break upon being reduced less than one-tenth of this diameter (brittle); class 2 (slightly malleable) admit of being reduced from one to three-tenths (or nearly $\frac{1}{4}$ in bulk); class 3, from three to five-tenths ($\frac{1}{4}$ to $\frac{1}{2}$), being semi-malleable; class 4, from five to seven-tenths ($\frac{1}{2}$ to $\frac{3}{4}$). The metals belonging to this class admit of being hammered down to thin plates, but crack more or less on the margin, and therefore, although "malleable," are not ranked perfectly so. Class 5 includes all those metals that may be beaten down nine-tenths of their thickness without breaking or cracking—the margins remaining entire—and are characterized as perfectly malleable. They may be further classified according to the usual tables.

When at a loss as to the precise place of a metal under examination, the nature of its cleavage or its subsequent "behavior" under the hammer often assists decision; or it is represented by two figures, as in the case of other qualities.

FUSIBILITY.

The scale in the table is arranged to correspond to the actual melting point as indicated by Fahrenheit's thermometer, taking the unit to represent 100°. Class 1 includes those metals which melt at 100° and under 200°; and so of the others. Since the most careful measurements are liable to error by a few degrees, a latitude of ten degrees is allowed, (and it will be seen by reference to the table that the results of different experimenters usually vary still more widely,) so that if a substance melts at 90°, or a little upwards, it is placed in class 1; if at 190°, in class 2, &c.

It may be thought that the *mean* of two whole numbers ought to be adopted, as the unit of measure, in classification; that, for instance, metals melting at 150°, instead of 100°, should be taken as the true type of the class expressed by the unit 1, allowing a range of deviation so as to include 50° on either side. But the scale was arranged with a view to the employment, when desired, of decimals correspond-

ing to the figures which express the absolute melting point. Thus the fusibility of a metal melting at 150° or 175° would, to be definite, be indicated by 1·5 or 1·75: while, if its precise melting point was not determined, although found by comparative tests to fall somewhere between two numbers, we should make use of both to express it; as, 1—2, or 1·5—2, which indeed, in some cases, is about as near as we can approximate the truth by actual measurement.

The table shows both the temperature of liquefaction and that of congelation, as indicated by the mercurial thermometer (Fah.), the first being assumed as the "melting point." It also exhibits in the same view, the results of different experimenters, varying somewhat from mine, but as much among themselves.

For abbreviations, I prefer using the initials of the English names of the metals, instead of the Latin.

Scale of Hardness, Flexibility, and Malleability, with Examples.

Hardness.		Flexibility.		Malleability.	
Class.	Types.				
1.	Lead.	1.	Bismuth. 1 An. 3 T. 2 An. 1 Cop. 12 T.	1.	*Brittle.* Antimony. Bismuth.
2.	Tin. 1 B. 3 L.	2.	6 B. 74 T.	2.	*Slightly malleable.* 1 An. 3 T. 8 B. 5 L. 3 T. 2 An. 1 Cop. 12 T.
3.	2 L. 1 T. Bismuth.	3.	Zinc. 8 B. 5 L. 3 T. 1 An. 6 T.	3.	*Semi-malleable.* 1 B. 1 L. 2 T. Zinc (cast).
4.	2 T. 1 L.	4.	1 B. 3 L.	4	*Malleable.* 1 An. 6 T.
5.	1 An. 6 T. Cadmium.	5.	1 A. 9 T. Cadmium. Lead. Tin. Alloys of L. and T.	5.	*Perfectly malleable.* 1 B. 3 L. Cadmium. Lead, Tin, &c.
6.	1 An. 3 T. 2 An. 1 Cop. 12 T.				
7.	Zinc.				

Scale of Fusibility, with Examples.

Classes and Divisions.	Metals and Alloys.	Melt. Liqu.	Melt. Cong	Melting-Point, Fah., according to different Authors.
1. 1·5	1 Cd. 4 B. 2 L. 1 T.	150°	150°	Varying not far from 70° C. (158° F.). Silliman's Journal.
1. 1·5	3 Cd. 15 B. 8 L. 4 T.	150°	150°	Soft betw'n 131° & 140°. Near 140°, perfectly fluid. Lipowitz.
1. 1·5–2	1 Cd. 7 B. 6 L.	180°	178°	
2. 2·	8 B. 5 L. 3 T.	200°	198°	202°, Graham, Chem. 200° to 212°, according to others.
3. 3·	1 B. 1 L. 2 T.	310°		
3. 3·5	1 L. 2 T.	338°	336°	About 360°, Graham. 340°, Austen.
4. 4+	Tin.	426°	420°	442°, Crichton and Rudberg (Graham), Brande, and others. 445·6°, Kupffer (Graham). 410°, Artist's Manual. 450°, Webster. 420° and 440°, Appleton's Dict. Mech.
4. 4·5–5	Bismuth.	476°	470°	497°, Crichton (Gr'm). 507°, Rudberg (ib.) 476°, 497°, Brande 476°, Parkes, Phillips, and others. 480°, Overman.
5. 5·	207 + L. 58 + T. (Pb_2 Sn).	Melt?		Congeals 518°, Graham.
6. 6·	Cadmium.	At melting p't of lead.		442°, Stromeyer (Graham and others). 450°, Sanders. 360°, Daniell (New Amer. Cycl.). 550°, Overman.
6. 6·	Lead.	Below a red heat.		612°, Crichton (Graham). 600°, Webster and others. 590°, Morveau (Artist's Manual). 594°, Overman.
7.	Zinc.	Near a dull red heat.		773°, Daniell (Graham), Brande, and Phillips. 680°, Parkes. 666° and 700°, Appleton's Dict. Mech. 700°, Webster. 770°, Overman.
8.	Antimony.	At a fair red heat.		810°, Parkes, Brande, and others. 1060°, Silliman's Chem. 797° (estimated), Graham. 800° and 850°, Phillips. 800°, Webster. 932°, Overman. 842°, New Amer. Cycl.

CADMIUM ALLOYS.—BINARY COMBINATIONS.

Cadmium with Antimony.

The compounds of cadmium and antimony in the proportions of 1 Cd. 2 A., and 4 Cd. 1 A., are hard and very brittle. They melt at a temperature not varying much from that representing the mean melting temperature of the constituents. They do not disclose properties that give promise of usefulness. In physical characters, they agree substantially with the following, a brief description of which will suffice for the class.

27 Cd. 64 A. This alloy has a dark steel-grey color with a leaden hue and a bright metallic lustre. It is hard and extremely brittle; the fracture is crystalline, and presents something of a conchoidal, and more of a plicated appearance. In hardness, to judge by the ordinary method, it would rank with nickel—it scratches zinc, antimony, and copper—but it is fragile under pressure. It is neither flexible nor malleable in the least appreciable degree. Its fusibility is very nearly the same as that of zinc.

Cadmium with Bismuth.

Cadmium alloyed with bismuth is rendered brittle, though the latter be used in very small proportion. There is little difference in this particular whether the bismuth constitutes an equal part or but one-twelfth of a part. These compounds are quite hard and rigid, and they present a very brilliant appearance unless bismuth largely predominates, when they are disposed to tarnish and oxidize.

1 Cd. 1 B.
55 Cd. 70 B.
1 Cd. 2 B. } The alloy produced by combining the metals in any of these proportions is exceedingly handsome and brilliant. It is of a bright greyish-white color, with a faint reddish tint. The free surface (or that part which, in casting, is free from contact with the sides of the ingot-mould) is smooth, beautifully rounded off, and highly polished. In casting, it takes sharp outlines. It breaks with an even and finely crystalline fracture, the crystals showing like fine angular grains. In fusibility, it ranks with the most fusible mixture of bismuth and lead, and of bismuth and tin.

Hardness 5. Flex. 1. Mall. 1. Fusib. 2·5—3 (near 275° F.).

Cadmium with Lead.

These metals form bright handsome alloys, which are harder, and mostly less fusible, than the corresponding compounds of tin and lead. They are perceptibly harder when newly made than after standing awhile (which would appear to be the case with some other alloys). They also part with much of their brilliancy, assuming more of a leaden hue. Contrary to what would be inferred from the behavior of other alloys, they are less fusible when composed of nearly equal proportions of their constituents, than when the lead predominates to the extent of from four to six parts to one, becoming less fusible up to the point at which the proportions are equalized. Passing from this point, on the other side, the fusibility remains nearly identical,

whether the cadmium be in the ratio of two to one of lead, or six to one, being nearly the same as that of bismuth; but the hardness increases with the addition of cadmium. A few examples will suffice:—

1 Cd. 1 L. Color, bright grey. H. 4—5. Fl. 4. M. 5. Fu. 4·5—5 (about 480°).

1 Cd. 4 to 6 L. Color, leaden-grey (at first brilliant). H. 4—5. Fl. 4. M. 5. Fu. 4·5 (near 440°).

6 Cd. 1 L. Color, bright white, with a bluish hue. Retains its lustre. Less flexible than the preceding, though ranking in the same class. H. 5—6. Fl. 4. M. 5. Fu. 4·5—5 (about 470°).

Cadmium with Mercury.

Contrary to what might be inferred from general descriptions and the case of other amalgams,* the compounds of cadmium and mercury are remarkable for their hardness and tenacity.

1 Cd. 1 M. Form a very tough and malleable *alloy* (for it cannot be strictly called an "amalgam") of a bright silver-white color, and that melts between 350° and 400°, a higher temperature than the mean melting-point of its constituents.† It is harder than an alloy of 2 tin and 1 lead, but softer than cadmium. Its fracture is jagged and hackley. H. 4—5. Fl. 5. M. 5. Fu. 3·5—4.

1 Cd. 2 M. Resembles the preceding nearly in color and character, although somewhat less tenacious, and more fusible. It melts below 280°, but does not soften the least in boiling water. Fusibility 2—3; other qualities undetermined, but may be inferred from the other formulæ. (According to Nickelson's Dictionary of Chemistry, by Ure, "100 mercury and 27·78 cadmium, fuses at 167° F.")

28 Cd. 41 M. H. 4. Fl. 5. M. 5. Fu. ?

Cadmium filings mixed into a paste with mercury at ordinary temperature, form an amalgam that solidifies in three or four hours. It cuts with a smooth surface, has much tenacity, and on breaking shows a rough fracture.

Cadmium with Tin.

Cadmium and tin form hard, malleable alloys of a silvery lustre—the color being such as might be expected from the blending of the two—white, without the yellowish tinge of tin, or the violet-blue shade of cadmium, but approximating to either, as the one or the other metal predominates in the alloy. They are flexible, and perfectly malleable, unless the constituents be contaminated with other metals; a very little bismuth renders them brittle.

2 Cd. 1 T. Nearly resembles cadmium in appearance, but is more

*See remarks on the subject, in vol. xl., page 114.

†Two parts of tin and one part of mercury form a compound so frail and brittle as almost to fall to pieces in handling (equal parts being still more frail). It requires a temperature of about 300° or upwards to melt it. An amalgam made of two parts of an alloy composed of 2 tin and 1 lead, and 1 part of mercury, is also very fragile, and does not melt in boiling water (212°), though it softens very slightly in it. These facts seem to require a modification of the inference stated, upon too hasty generalization, in the paper just referred to, that "the fusibility of the compounds of cadmium and mercury is nearly that of the mean of their constituents," and that the same "appears to be the case with other amalgams." It would appear that although mercury combined with cadmium does not act as a fluidifying agent, but actually the reverse, it may act as such, or be perfectly passive, in other combinations—a point of interest worth examining.

silvery. Free surface, clouded or slightly "frosted."* H. 5. Fl. 4. M. 5. Fu. 4.

1 Cd. 1 T. Silver color. H. 5. Fl. 4—5. (?) M. 5. Fu. 3·4.

1 Cd. 2 T. Very brilliant. Free surface highly polished. H. 5. Fl. 5. M. 5. Fu. 3·4.

As the proportion of tin is increased, the alloy becomes softer and less fusible.

Cadmium with Zinc.

4 Cd. 6 Z. Zinc-color. H. 7+ M. 4—5. Fu. 5—6.

TERNARY COMBINATIONS.

Cadmium with Antimony and Tin.

These form very hard alloys.

1 Cd. 1 A. 3 T. A brittle alloy, though quite strong; somewhat harder than zinc. H. 7. Fl. 1. M.—2. Fu. 5.

1 Cd. 2 A. 12 T. H. 6—7. Fl. 2. M. 2—3. Fu. 4·5.

1 Cd. 1 A. 9 T. A very strong alloy, of a compact structure and bright surface. It casts with little perceptible shrinkage, and makes a handsome and perfect die from a sand mould. Free surface, full and even, and exhibiting a finely frosted appearance. H. 6. Fl. 3. M. 3—4. Fu. 4—4·5.

Cadmium with Bismuth and Lead.

These compounds are remarkable for fusibility, as described in a late number of this Journal; they do not require further notice here, except for comparison with the tables.

1 Cd. 2 B. 1 L. H. 4·5. Fl. 2. M. 2. Fu. 2+
1 Cd. 7 B. 6 L. H. 3+ Fl.—3. M. 2+ Fu. 1·8.
1 Cd. 9 B. 8 L. H. 3+ Fl. 3+ M. 2+ Fu. 2.

Cadmium with Bismuth and Tin.

The compounds of these metals are remarkably brittle in any proportions of combination, unless the tin be greatly in excess. Thus, alloys composed of 12 parts cadmium, 1 of bismuth, and from 1 to 24 tin; or 1 cadmium, 1 bismuth, and 1 to 24 tin; or 1 cadmium, 12 bismuth, and 250 or less of tin; are all very brittle, requiring nearly twice as much tin as the largest amount named, in order to render them perfectly malleable. They do not seem to differ materially in hardness whether the tin be used in the smaller or larger proportions mentioned. They approach more or less to a pure silver-white, and are very brilliant.

1 Cd. 2 B. 1 T. A beautiful clear-white alloy, having a very slight roseate tint; free surface, frosted. It is very fusible and very brittle; it breaks with a smooth, compact, steel-like fracture. H. 5. Fl. 1. M. 1. Fu. 2+

1 Cd, 5 B. 4 T. Similar in appearance to the preceding; fracture

* Clouded—Presenting a white opacity, like a white film or cloud.
Frosted—Having the appearance of fine white crystallization, like hoar-frost.

the same. As to fusibility, it has a wide range, being fluid at 240°, and still soft at 220°. H. 5. Fl. 1. M. 1. Fu. 2·4.

68 Cd. 95 B. 216 T. Appearance and fracture like the last. H. 5. Fl. 1. M. 1. Fu. 2·5—3.

5 Cd. 4 B. 140 T. General appearance the same. Free surface, smooth and polished. Very brilliant. Fracture, rough and hackley. H. 5. Fl. 2. M. 2. Fu. 4+ (same as tin).

Cadmium with Lead and Tin.

From these are produced alloys combining the qualities of fusibility and tenacity in an eminent degree, rendering them very desirable as solders—the alloys in general use for this purpose, that melt at as low a temperature, being much more brittle.

The following formulæ (secured by patent, March, 1860) furnish the most fusible form of these alloys:—

1 Cd. 1 L. 2 T. White and glistening. H. 5. Fl. 5. M. 5. Fu. 2·8.

1 Cd. 2 L. 4 T. Resembles the preceding. H. 4. Fl. 5. M. 5. Fu. 2·8.

QUATERNARY COMBINATIONS.

Cadmium with Antimony, Copper, and Tin:

Cadmium in connexion with these metals gives greater hardness to the alloys without materially modifying their other qualities. For this purpose, it should be used in rather small proportions. In the following instances, two parts instead of one do not increase the hardness, while four parts diminish it.

1 Cd. 1 A. 1 Cop. 10 T. produce a very hard yellowish-white alloy, which, though brittle, is strong. It has a fine granular fracture. It casts without shrinkage. Free surface, full and rounded, somewhat crystalline, and has a saffron stain. It is an example of alloys having a wide range between the states of partial and complete fluidity. It softens at the heat which melts bismuth, and is but imperfectly fluid at that which melts lead. H. 7. Fl. 1. M. 2. Fu. 6.

1 Cd. 2 A. 1 Cop. 12 T. This is a still more desirable alloy, being very white and bright, equally hard, and more fusible. It is whiter than silver, being more of a pearl or milk-white color. Free surface, full and round, and finely crystalline. In other respects similar to the last. H. 7. Fl. 1. M. 2. Fu. 5.

Cadmium with Bismuth, Lead, and Tin.

Combined in certain proportions, these metals produce the most fusible alloys known. The compounds which manifest this property most strikingly, have been heretofore described. (They were embraced in letters patent, granted 1860.) It only remains to give a few formulæ for comparison with other alloys.

1 Cd. 1 B. 1 L. 1 T. Equal parts of the metals form a white alloy, rather hard and brittle, breaking with a close-grained fracture. H. 4—5. Fl. 3. M. 4. Fu. 2+

1 Cd. 4 B. 2 L. 1 T. } These are nearly identical in charac-
1½ Cd. 7½ B. 4 L. 2 T. } ter and properties. In thin plates, they

are flexible, otherwise rather brittle. Color, white, with a faint purplish shade. Fracture, smooth and close-grained. H. 4. Fl. 3. M. 2. Fu. 1·5.

1 Cd. 6 B. 4 L. 2 T. This is similar to the last named, but is preferable for casting purposes. It melts at about 160° F.

1 Cd. 1 B. 4 L. 2 T. H. 4. Fl. 4. M. 4. Fu. 3.

12·08 Cd. 15·75 B. 7·69 L. 4·38 T. This is adduced merely as an instance of a very fusible alloy having a wide range between the points of perfect liquefaction and solidification. Heated by the side of the thermometer bulb, in water, it became soft at 170°, and at 210°—the highest point indicated by the thermometer, the water boiling—nearly fluid, not perfectly, but sufficient to recover from indentations impressed upon it. On cooling, it was at 200° only semi-fluid, so as to retain indentations, still quite soft at 175°, and not perfectly solidified until the mercury fell to 150°.

The uses of the foregoing alloys will be suggested by their qualities.

I may be permitted to repeat, that these experiments were not undertaken with a view to methodical investigation; and these descriptions must fall far short of what in such case would be expected. But having to do with metals, the frequent want of one possessing a particular quality or combination of qualities, led me, from time to time, to experiment with alloys, with a view to their improvement in such particular—noting more especially whatever promised the desired result. In such cases, the development of any unexpected property, and sometimes merely baffled curiosity, naturally stimulated the inquiry beyond its original purpose. But defective as these descriptions may be, it is hoped that, so far as they go, they will be found to give reliable information upon a class of metallic combinations which appear not to have been described hitherto, if examined.

INDIANAPOLIS, Feb. 1, 1862.

For the Journal of the Franklin Institute.

Analysis of the Gamut in the Major and Minor Modes.

By C. J. W., Jr., Germantown, Pa.

The octave of musical sounds, as is well known, is composed of five whole tones and two semitones, or of twelve semitones.

In the major mode, to which we shall first turn our attention, the two semitones are placed between the third and fourth, and the seventh and eighth notes of the scale.

This position of the semitones is dictated by no arbitrary law, as might at first appear, but is determined by the sense of melody inherent in the soul of man: it is indispensable, therefore, that the relationship should be preserved throughout all modulations and transpositions of major keys.

As there is no difference between one octave and another, with regard to the positions of the tones and semitones, any course of reasoning applied to one, applies equally to all, be they pitched high or low; the only difference between a note and its octave, being, that the

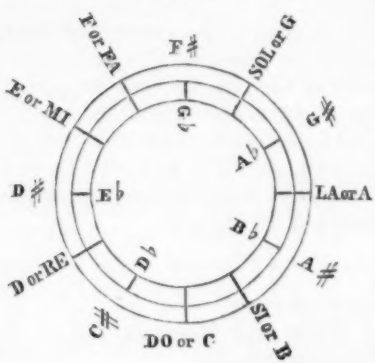
vibration by which the higher note is produced, has twice the velocity of that which produces the lower.

The rule to be observed in modulating from the natural key—the key of Do, or C—into a key represented by flats, is, that the flats shall succeed each other by ascending fourths, or, which is equivalent, by descending fifths, commencing with the seventh of the scale—Si, or B—for the first flat; while in modulating into a key represented by sharps, the rule is reversed, for the sharps must succeed each other by ascending fifths, or descending fourths, commencing with the fourth of the scale—Fa, or F—for the first sharp. Now these rules are entirely dependent upon the law already referred to, controlling the relative positions in the major mode of the tones and semitones of the scale, and though usually dictated without regard to the principles upon which they are based, a brief examination into the manner in which the position of the semitones is affected by the additions in question, will nevertheless render them sufficiently apparent.

Let the annexed diagram, Fig. 1, represent the octave in the key of Do, or C major; the long marks representing the natural notes, and the short marks, the flats or sharps.

The circular form of the diagram is selected as peculiarly adapted to the investigation of the subject before us; ascending or descending octaves being but a repetition of the same notes, ever returning, like the circle, to the point of commencement.

Fig. 1.



By an examination then of this diagram, with a view to modulating into other keys, it will readily be discovered that there are but two notes—the fourth and the seventh of the scale—that can be successfully attacked without disturbing the relative position of the tones and semitones, so necessary to be preserved.

Suppose, for example, we try the experiment of advancing the first note of the scale, Do, one semitone. The interval between the semitones of the octave thus modified, will be reduced, in one direction, to one whole tone—while in the other direction, it will be increased to four whole tones. This distribution of the semitones evidently belongs to no major key whatever, and we cannot therefore commence our modulations by disturbing the *first* of the scale.

In order to complete the modulation now initiated, and to restore the equilibrium of the octave, it will be necessary to increase the interval between the semitones in one direction, and to diminish it in the other. This may evidently be accomplished by advancing the note Fa, a semitone. The interval between Re and Fa sharp, is composed of two whole tones; while the interval from Sol to Do sharp, is

composed of three whole tones. It is evident, therefore, that by taking Re for the keynote, we have modulated into the key of two sharps; but at the same time, it will be observed that the equilibrium of the octave has only been preserved by the modification of two notes, instead of one, as was proposed.

Convinced, therefore, that this is not the initial modulation from the natural scale, we will proceed by trying the effect of augmenting Re, the second of the scale.

The interval between Re sharp and Mi, is but one semitone; we shall thus have three semitones in our scale, two of which are in juxtaposition. It will be readily admitted, therefore, that the second of the scale is not the proper note to attack—observing that the distribution of the semitones can only be re-adjusted by the augmentation of a number of other notes of the scale. For example: Re sharp evidently requires that Fa should be sharpened in order to separate the contiguous semitones; but this is not yet sufficient, for there now exists between the two semitones one full tone, instead of two, as required. It is indispensable, therefore, that Sol should be sharpened. We have now accomplished the necessary condition of two full tones, in one direction, between the semitones; thus there yet remains the redundancy of semitones, however, to disqualify the scale. Further modification, therefore, is still required. Fortunately, this latter difficulty may be easily overcome, but one additional change being requisite. By the removal of Do, to Do sharp, and the assumption of Mi for the keynote, two whole tones will be found to exist between Mi and Sol sharp, and three whole tones between La and Re sharp. Thus the order of the tones and semitones of the scale is fully restored.

It appears, from the above investigation, that the experiment of modulating by the sharpening of the second of the scale, has required the modification of three additional notes before the octave could be restored to its original condition.

By pursuing a similar course, it may be shown that the first and only modulation of a scale, involving the disturbance of no other note, is to be accomplished by applying the modification to its fourth, or seventh. These two, therefore, will be found to be the initial modulations of which we are in search—the one introducing us to a key represented by flats, the other introducing us to a key represented by sharps. It remains to be shown what effect will be produced upon the scale by the application of our modifications to these two notes successively.

It is evident from the position of the semitones of the major scale, that the fourth cannot be flattened, or the seventh sharpened, without becoming identical with other notes of the scale. In view of this, therefore, we shall apply the sharp to the fourth, and the flat to the seventh.

If Fa, the fourth of the natural scale, be augmented by the introduction of a sharp into the signature, the order of the semitones will be precisely reversed, without otherwise interfering with their relative position; the interval between the note Do and the first semitone of

the scale—formerly composed of two full tones—will thus be increased to an interval of three full tones; meanwhile, the interval between the semitone as now placed and the second semitone of the old scale, immediately preceding the fundamental note Do, will be correspondingly decreased, and will comprise but two full tones. It is abundantly evident, therefore, that the note Do can no longer do duty as the keynote of the scale thus modified, but must yield that distinction to some other of its six competitors—it remains to be shown which of these is to become the successful candidate.

Through the inversion of the order of the semitones thus established, the interval between the note Do and the first semitone, is an interval proper to the separation of the first and second semitones of the major scale, and the interval existing between the advanced semitone and the second semitone of the natural scale, is that proper to the separation of the keynote and the first semitone. The first semitone of the original scale, therefore, becomes the final or leading semitone of a new scale, and as in the formation of this semitone the fourth of the old scale was advanced, the note immediately succeeding this, or the fifth, will become the fundamental note. Sol will, therefore, be the keynote of the new scale.

By the arrangement now proposed, the equilibrium of the octave will be seen to be completely restored, and the order of the tones and semitones, in perfect accordance with the principles upon which the major scales are based.

Through the augmentation, therefore, of one single note, we have effected a modulation into a new scale, in which the eighth of the old scale appears as the fourth, and in which the fifth of the old scale appears as the eighth. In other words, by sharpening the fourth of a scale, we have modulated into its dominant.

By pursuing a similar course of investigation, it will be found that the initial modulation to be made from our new key of Sol, is to be accomplished, in like manner, by the augmentation of *its* fourth, thus modulating in turn, into its dominant. For the next scale in order, therefore, we shall have Do, or C sharp, in addition to Fa sharp, and Re, the fifth of the present scale, for the keynote.

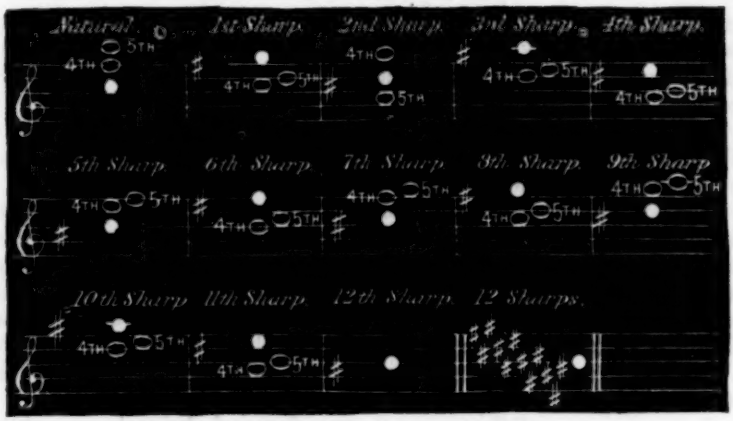
The process of sharpening the fourth of each new scale, and thereby producing the scale of its dominant, may be continued until every note of the octave has, in turn, been reached, and we arrive again at the identical point—the key of Do natural (or its equivalent)—from which we originally set out.

Proceeding upon this principle, the modulations represented by sharps will succeed each other in the following order. (See fig. 2.)

It will be seen that the fundamental note of each key is represented by a solid note, such as a crotchet without the stroke, while the dominant and subdominant are represented by open notes, such as a minim. Observe, also, that only the additional sharp of each key appears in the signature, it being perfectly understood, however, that to every key belong all the sharps of the preceding keys, equally with the one introduced.

By reference to the table below, it will be seen that the augmentation of the second of the natural scale—one of the changes proposed in the search for the initial modulation, and rejected on account of the disarrangement of the semitones which it produces—is the fourth, instead of the first, in the order of modulations; and that it requires the introduction of three auxiliary sharps before the equilibrium of the octave can be restored.

Fig. 2.—Table of Progressive Sharps.



This law of succession of sharps by ascending fifths, affords an easy rule for finding the keynote indicated by any number of sharps proposed; or, *vice versa*, for finding the number of sharps required to produce any given keynote without the labor of counting them over in the ordinary way. The latter rule is particularly convenient in its application to the transposition of music.

The rule for the solution of the first proposition is as follows: multiply by four the number of sharps proposed, and divide the product by seven. The remainder will give the number of notes above the keynote of the natural scale, that the keynote required will be found.

For example: suppose it were required to find the keynote of the scale of five sharps.

Here, five multiplied by four, equals twenty, and twenty divided by seven, leaves a remainder of six. Six notes above Do natural, therefore, will the keynote of five sharps be found. Si, or B is the note; and by reference to the table it will be seen to be the keynote of the scale proposed.

Again: suppose the keynote of twelve sharps were required.

In this case twelve is to be multiplied by four, equal to forty-eight. Forty-eight divided by seven, leaves six for a remainder. B is again, therefore, the keynote required; in this instance, however, it will be B sharp—that note having already been sharpened in the scale. But B sharp is practically the same note as C natural—the same key answering for both in all keyed instruments. We have again, therefore, returned to the original key of Do natural.

To the solution of the second proposition—that of finding the number of sharps required to produce any given keynote—may be applied the following rule.

Find the number of notes that the given keynote is placed above the keynote of the natural scale of Do, and if this number is not divisible by four, without a remainder, add thereto the first multiple of seven that will render it so. The number of times that four is contained by this sum will be the number of sharps required.

For example: suppose a piece of music arranged in the key of Fa natural, were required to be raised one full tone; the key sought would then be the key of Sol natural. The question to be solved is to discover the number of sharps that will be required to produce the key of Sol natural.

Sol natural is four notes above Do natural, and four is divisible by four, once. The key of Sol natural requires, therefore, the introduction of but one sharp into the signature.

Suppose, for a second example, that the number of sharps necessary to produce the key of B natural were required. Now B natural is six notes above Do natural, and six added to fourteen—the first multiple of seven, which added to six makes a sum divisible by four, without a remainder—makes twenty, and twenty is divisible by four, five times. Five sharps, therefore, are required to produce the key of B natural.

A brief investigation into the rationale of the rules above applied will render it sufficiently obvious.

In consequence of the nomenclature of accords being in accordance with the number of sounds, and not the number of notes, of which they are composed, each accord gives the impression of containing one note more than is actually embraced within its limits. Thus a second includes but one note, though composed of two sounds; a third includes but two notes, though composed of three sounds; a fourth includes but three notes; a fifth, but four notes, and an octave, but seven notes. As the addition of each sharp to the signature raises the keynote of the scale a fifth, or four notes, the number of sharps introduced, multiplied by the number of notes contained in a fifth, will give the number of notes that the keynote is raised above the keynote of the natural scale; divide this number by the number of notes contained in an octave, and the remainder, if any, will necessarily give the number of notes above Do, that the keynote of the proposed scale will be placed.

The rule suggested for finding the number of sharps required for any given keynote, being but the converse of the one just explained, evidently requires no further demonstration.

Of the introduction of accidental sharps, it is likewise unnecessary to speak; they, only producing temporary modulations of the key, obey the same laws as those already investigated. We shall, therefore, proceed to the consideration of modulations effected by the introduction of flats into the signature.

By referring once more to the circular diagram, and pursuing a course of investigation similar to that already applied to the subject of

sharps, it will be seen, that, as the fourth of the scale is the only note to be sharpened, so the seventh is the only note to be flattened, consistently with the preservation of the relative positions of the tones and semitones of the major octave.

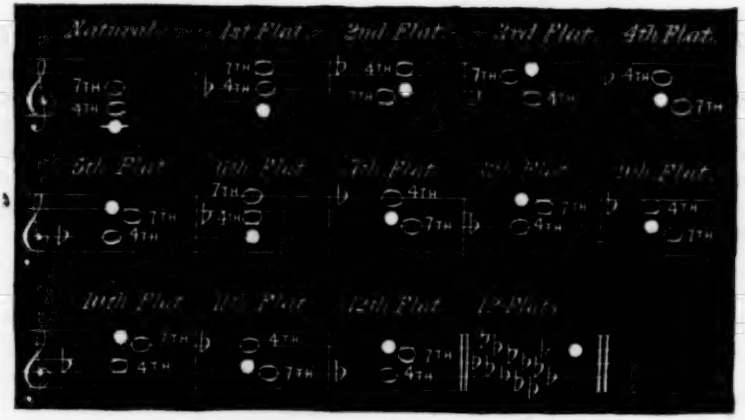
By flattening the seventh, therefore—which in the natural scale is the note Si, or B—we shall evidently diminish the interval before existing between the first and second semitones, by one full tone, in one direction, while at the same time we increase, to a similar extent, the interval existing between them in the other direction. We have thus produced another new scale, in which the first semitone of the old scale—now, by virtue of the change which we have introduced—preceded by three full tones, appears as the last or leading semitone. The note immediately succeeding this semitone must consequently be the fundamental note of the scale. This note is Fa, or F—the fourth or subdominant of the original scale.

By the acceptance of this arrangement the equilibrium of the octave will be fully restored; the tones and semitones occupying their appropriate positions.

Through the diminution, therefore, of a single note, we have produced a new scale, in which the fourth of the original scale appears as the eighth, and in which the seventh appears as the fourth. In other words, by flattening the seventh of the scale we have modulated into its subdominant.

This process of diminishing the seventh may be continued, as in the augmentation of the fourth—until every note of the octave has in turn been reached, and we return practically to the keynote with which we commenced. Each additional flat will form a new scale, the fundamental note of which will be the fourth, or subdominant, of that by which it is immediately preceded.

Fig. 3.—Table of Consecutive Flats.



That flats should succeed each other necessarily, by ascending fourths, thus becomes obvious; for, as the entire scale is elevated a fourth by each additional flat, the seventh of the scale is likewise raised with it—

and, as the seventh of the scale is the note to which the additional flat is invariably applied, the additional flat will unquestionably be a fourth above the one immediately anterior. The previous flat, or last flat but one, thus becomes the keynote of each scale of flats, that being the note immediately following the last semitone. The same principle was shown to determine the keynote in a system of sharps; it being recollected, however, that a flat takes its name from the *succeeding* note, while on the contrary the name of the sharp is derived from the *preceding* note.

The order of modulations by flats is shown in the above table, in which it will be observed, that only the last note flattened in each key is introduced; and also, that the keynote is represented by a solid note, while the fourth and seventh of the various scales are represented by open notes, as in the table of sharps on a preceding page.

The elevation of the keynote by fourths, effected by the addition of flats to the signature, enables us to establish rules for finding the keynote required for any number of flats, as well as the number of flats required for any keynote, precisely similar to those applied to like cases in scales represented by sharps; except, that the number of flats is to be multiplied by three—the number of notes embraced in the interval of a fourth—instead of by four, the number embraced in the interval of a fifth. For example: let it be required to find the keynote indicated by the signature of six flats. Here, six multiplied by three equals eighteen, and eighteen divided by seven leaves a remainder of four. Four notes above Do, therefore, will be the keynote required; thus Sol is the keynote of a scale of six flats. But the keynote of any scale of flats has been shown to be the last flat but one in the signature. This note Sol, therefore, has been flattened in the antecedent modulation of the series. Sol *flat* is consequently the keynote of six flats.

It would evidently be superfluous to introduce any demonstration of this latter rule, as it would merely be a reiteration of the steps already taken, when upon the subject of modulations effected by sharps.

As an example of the converse of the proposition, suppose it were required to find the number of flats indicated by the keynote of La, or A flat. Now La is five notes above Do; five added to seven equals twelve, and twelve is divisible by three four times. Four flats, therefore, are required to produce the key of La flat.

Without further multiplication of examples, we shall now turn our attention to the subject of identical keys.

(To be Continued.)

Mode of Repairing the Silvering of Looking-Glasses.

The following notice is from *Dingler's Polytechnisches Journal:*—The mending of the silvering of looking-glasses is considered a very difficult operation. Recently, however, a method has been described in the Polytechnic Society of Leipsic, which several trials recommend as simple and practical. When the silvering is damaged, the place is

uncovered and cleaned by gentle rubbing with fine cotton until there is no trace of dust or grease. This cleansing must be done with the greatest care, if we would not leave a stain around the place. Then, with the point of a knife, a piece is cut from the silvering of another glass, of the same shape with that removed, but rather larger. A small globule of mercury (for instance, the size of a pin's head for a surface the size of the finger-nail) is dropped upon the cut piece. The mercury immediately spreads, penetrates the amalgam as far as the cut, and allows the piece to be removed, and put on the desired place. This manipulation is the most difficult part of the work. It is then gently pressed on the spot with cotton; it soon hardens, and the glass looks as if it were new.—*Cosmos.*

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

(Continued from page 120.)

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Calculated weight of metal contained in pillar in lbs.	Calculated breaking weight in tons from formula, $w = 46{\cdot}65 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$.	Calculated breaking weight in tons from formulæ, $w = 46{\cdot}65 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$ $Y = \frac{We}{W + \frac{2}{3}e}$.	Calculated breaking weight per square inch in tons.
7½	6½	4½	13·846	362·79		432·81	27·99
9	"	"	16·615	435·35		374·47	24·21
10½	"	"	19·384	507·91		325·20	21·03
12½	"	"	23 076	604·66		271·69	17·57
15	"	"	27·692	725·59		220·34	14·24
17½	"	"	32·307	846·52		181·72	11·75
20	"	"	36·923	967·45	147·92		9·56
30	"	"	55·384	1451·18	74·24		4·80
					$w = 42{\cdot}347 \frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}68}}$.	$w = 42{\cdot}347 \frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}68}}$ $Y = \frac{We}{W + \frac{2}{3}e}$.	
6	7	5	10 2-7	353·81		622·70	33·03
8	"	"	13 5-7	471·75		521·12	27·64
10	"	"	17 1-7	589·69		437·49	23·20
12	"	"	20 4-7	707 62		370·08	19·63
14	"	"	24	825 56		315·99	16·76
16	"	"	27 3-7	943 50		272·41	14·45
18	"	"	30 6-7	1061 44		237·04	12·57
20	"	"	34 2-7	1179·38	201·41		11·03
22	"	"	37 6-7	1297·31	172·43		9·14
24	"	"	41 1-7	1415·25	149 63		7·93
26	"	"	44 4-7	1533·19	131·33		6·96
28	"	"	48	1651·13	116·38		5 17
30	"	"	51 3-7	1769·07	104·00		5·51

Table showing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron with Both Ends Rounded, as deduced from Mr. Hodgkinson's formulæ.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula, $w = 14{\cdot}9\frac{D^{3.76}}{L^{1.7}}$.	Calculated breaking weight in tons from formulæ, $w = 14{\cdot}9\frac{D^{3.76}}{L^{1.7}}$, $Y = \frac{wc}{w + \frac{4}{9}c}$.	Calculated breaking weight per sq. inch in tons.	Ratio of strength of pillars, same dimensions, with *flat* ends.
6	7	10 2-7		810·60	21·06	1·39
8	"	13 5-7		596·19	15·49	1·50
10	"	17 1-7	447·45		11·62	1·61
12	"	20 4-7	328·20		8·52	1·80
14	"	24	252·54		6 56	1·94
16	"	27 3-7	201 25		5·22	1·96
18	"	30 6-7	164·73		4·28	1·96
20	"	34 2-7	137·71		3 57	1·96
6	8	9		1202·33	23 91	1·32
8	"	12		908·88	18·08	1·43
10	"	15		703·96	14·00	1·51
12	"	18	542·25		10·78	1·63
14	"	21	417·24		8·30	1·69
16	"	24	332 51		6·61	1·89
18	"	27	272·17		5·41	1·91
20	"	30	227·53		4·52	1·91
6	9	8		1682·96	26 45	1·27
8	"	10 2-3		1304·39	20·50	1·37
10	"	13 1-3		1028 46	16·16	1·45
12	"	16		827·10	13·00	1·51
14	"	18 2-3	649·70		10·21	1·63
16	"	21 1-3	517·76		8·13	1·76
18	"	24	423·81		6·66	1·86
20	"	26 2-3	354·30		5·56	1·86
6	10	7·2		2253·22	28·68	1·23
8	"	9·6		1786·18	22·74	1·32
10	"	12		1432·14	18·23	1·39
12	"	14·4		1166·12	14·84	1·46
14	"	16·8		964·67	12·28	1·51
16	"	19·2	769·45		9·79	1·63
18	"	21·6	629·84		8·01	1·74
20	"	24	526·53		6·70	1·82
6	11	6 6-11		2912 80	30·65	1·19
8	"	8 8-11		2356·24	24 79	1·27
10	"	10 10-11		1918·94	20·19	1·35
12	"	13 1-11		1581·19	16·63	1·41
14	"	15 3-11		1320·00	13·88	1·45
16	"	17 5-11	1101·08		11·58	1·52
18	"	19 7-11	901 30		9·48	1·63
20	"	21 9-11	753·46		7·92	1·72
6	12	6		3661·05	32·37	1·17
8	"	8		3015·58	26·66	1·24
10	"	10		2491·65	22·03	1·31
12	"	12		2076·43	18·35	1·36
14	"	14		1748·80	15·46	1·41
16	"	16		1489·09	13·16	1·46
18	"	18	1250·12		11·05	1·53
20	"	20	1045 06		9 24	1·62

Table showing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron, with Both Ends Flat, as deduced from Mr. Hodgkinson's formulæ.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula, $w = 44{\cdot}16 \frac{D^{3.55}}{L^{1.7}}$.	Calculated breaking weight in tons from formulæ, $w = 44{\cdot}16 \frac{D^{3.55}}{L^{1.7}}$, $Y = \frac{w\,c}{w + \frac{1}{4}c}$.	Calculated breaking weight per sq. inch in tons.	Ratio of strength of pillars, same dimensions, *rounded* ends.
6	7	10 2-7		1126·87	29·28	1·39
8	"	13 5-7		898·74	23·35	1·50
10	"	17 1-7		723·93	18·81	1·61
12	"	20 4-7		591·52	15·37	1·80
14	"	24		490·63	12·74	1·94
16	"	27 3-7	396·38		10·29	1·96
18	"	30 6-7	324·46		8·43	1·96
20	"	34 2-7	271·24		7·04	1·96
6	8	9		1591·59	31·66	1·32
8	"	12		1301·19	25·88	1·43
10	"	15		1068·65	21·26	1·51
12	"	18		886·34	17·63	1·63
14	"	21		705·91	14·04	1·69
16	"	24		631·38	12·56	1·89
18	"	27	521·23		10·36	1·91
20	"	30	435·74		8·66	1·91
6	9	8		2140·76	33·65	1·27
8	"	10 2-3		1787·55	28·09	1·37
10	"	13 1-3		1493·63	23·47	1·45
12	"	16		1255·95	19·74	1·51
14	"	18 2-3		1065·36	16·74	1·63
16	"	21 1-3		912·33	14·34	1·76
18	"	24		788·67	12·39	1·86
20	"	26 2-3	661·96		10·40	1·86
6	10	7·2		2773·82	35·31	1·23
8	"	9·6		2358·41	30·02	1·32
10	"	12		2001·00	25·47	1·39
12	"	14·4		1703·82	21·69	1·46
14	"	16·8		1460·05	18·58	1·51
16	"	19·2		1260·67	16·05	1·63
18	"	21·6		1097·16	13·96	1·74
20	"	24		962·17	12·25	1·82
6	11	6 6-11		3490·08	36·72	1·19
8	"	8 8-11		3013·88	31·71	1·27
10	"	10 10-11		2592·06	27·27	1·35
12	"	13 1-11		2232·45	23·49	1·41
14	"	15 3-11		1931·24	20·32	1·45
16	"	17 5-11		1680·59	17·68	1·52
18	"	19 7-11		1472·06	15·48	1·63
20	"	21 9-11		1297·91	13·65	1·72
6	12	6		4288·92	37·92	1·17
8	"	8		3753·75	33·19	1·24
10	"	10		3267·47	28·89	1·31
12	"	12		2843·51	25·14	1·36
14	"	14		2481·54	21·94	1·41
16	"	16		2175·42	19·23	1·46
18	"	18		1917·27	16·06	1·53
20	"	20		1699·22	15·02	1·62

Mr. Hodgkinson says, "The index of the power of the diameter, to which the strength of long pillars of cast iron, with rounded ends, is proportional, is 3·76, nearly, and 3·55 in those with flat ends; as appeared from means between the results of a great number of experiments; or the strength of both may be taken as following the 3·6 power of the diameter, nearly."

"In cast iron pillars of the same thickness, the strength is inversely proportional to the 1·7 power of the length, nearly."

"It has been stated that the strength of solid pillars with rounded ends, varied as $\frac{d^{3.76}}{l^{1.7}}$, and that of those with flat ends as $\frac{d^{3.55}}{l^{1.7}}$. This was when the former pillars were not shorter than about 15, nor the latter than about 30 times the diameter."

"In the research for the above numbers, I was led to conclude that, if the material had been incompressible, the 3·76 and 3·55 would each have become 4, and the 1·7 have been 2. In that case, the strength would have varied as $\frac{d^4}{l^2}$, which is the ratio of the strength of pillars according to the theory of Euler; which theory was intended to apply to the power of pillars to resist incipient flexure, whilst my inquiry was as to the breaking strength."

Table showing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron with Both Ends Rounded, as deduced from Mr. Hodgkinson's formulæ.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula, $w = 14{\cdot}9\frac{D^{3.6}}{L^{1.7}}$.	Calculated breaking weight in tons from formulæ, $w = 14{\cdot}9\frac{D^{3.6}}{L^{1.7}}$. $r = \frac{we}{w + \frac{1}{2}e}$.	Calculated breaking weight per square inch in tons.	Ratio of strength of pillars of same dimensions with *flat* ends.
5	2	30	11·71		3·72	2·96
8	"	48	5·26		1·67	2·96
14	"	84	2·03		0·64	2·96
20	"	120	1·10		0·35	2·96
5	3	20	50·41		7·13	2·50
8	"	32	22·67		3·20	2·96
14	"	56	8·75		1·23	2·96
20	"	80	4·77		0 67	2·96
6	4	18	104·16		8·28	2·36
8	"	24	63·87		5·08	2 80
10	"	30	43·71		3·47	2·96
14	"	42	24·67		1·96	2·96
20	"	60	13·45		1·07	2·96
6	5	14·4	232·60		11·84	2·02
8	"	19·2	142·63		7·26	2·49
10	"	24	97·60		4·97	2·82
12	"	28·8	71·59		3·64	2 96
14	"	33·6	55·08		2·80	2·96
16	"	38·4	43·90		2·23	2 96
18	"	43·2	35·93		1·82	2·96
20	"	48	30·04		1·52	2 96
6	6	12		417·63	14·77	1·86
8	"	16	274·96		9·72	2 21
10	"	20	188·15		6·65	2·57
12	"	24	138·01		4 88	2·83
14	"	28	106·19		3·75	2·96
15	"	30	94·44		3·34	2 96
16	"	32	84·63		2·99	2·96
18	"	36	69·27		2 44	2·96
20	"	40	57·91		2·04	2·96

Table showing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron with Both Ends Rounded, as deduced from Mr. Hodgkinson's formulæ.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula, $w = 14{\cdot}9\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$.	Calculated breaking weight in tons from formulæ, $w = 14{\cdot}9\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$ $Y = \frac{w\,c}{w + \frac{2}{3}c}$.	Calculated breaking weight per sq. inch in tons.	Ratio of strength of pillars of same dimensions with *flat* ends.
12	7	20 4-7	240 39		6·24	2·62
16	"	27 3-7	147·40		3 83	2·96
20	"	34 2-7	100·87		2·62	2·96
12	8	18	388·78		7·73	2·43
16	"	24	238·40		4·74	2 85
20	"	30	163·13		3 24	2·96
12	9	16	594·08		9·33	2·25
16	"	21 1-3	364·29		5 72	2·70
20	"	26 2-3	249·28		3·91	2·96
16	10	19·2	532·33		6·77	2·55
20	"	24	364·27		4·63	2·87
16	11	17 5-11	750 24		7·89	2·41
20	"	21 9-11	513·38		5·40	2·75
16	12	16	1026·20		9·07	2·28
20	"	20	702·22		6·20	2·63

Table showing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron with Both Ends Flat, as deduced from Mr. Hodgkinson's Formulæ.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula, $w = 44{\cdot}16\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$.	Calculated breaking weight in tons from formulæ, $w = 44{\cdot}16\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$ $Y = \frac{w\,c}{w + \frac{2}{3}c}$.	Calculated breaking weight per sq. inch in tons.	Ratio of strength of pillars of same dimensions with *rounded* ends.
5	2	30	34·71		11·04	2·96
8	"	48	15·61		4·96	2·96
14	"	84	6·02		1·91	2·96
20	"	120	3·28		1 04	2·96
5	3	20		126·47	17·89	2·50
8	"	32	67·20		9·50	2·96
14	"	56	25·95		3·67	2·96
20	"	80	14·15		2·00	2·96
6	4	18		246·70	19·63	2·36
8	"	24		179·02	14·24	2·80
10	"	30	129·54		10·30	2·96
14	"	42	73·11		5·81	2·96
20	"	60	39·87		3·17	2·96
6	5	14·4		470·08	23·94	2·02
8	"	19·2		355·42	18·10	2·49
10	"	24		275·33	14·02	2·82
12	"	28·8	212·18		10·80	2·96
14	"	33·6	163·27		8·31	2 96
16	"	38·4	130·11		6·62	2·96
18	"	43·2	106·50		5·42	2·96
20	"	48	89·03		4·53	2·96

Table showing the Strength of Solid Uniform Cylindrical Pillars of Cast Iron with Both Ends Flat, as deduced from Mr. Hodgkinson's formulæ.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula, $W = 44{\cdot}16\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$.	Calculated breaking weight in tons from formulæ, $W = 44{\cdot}16\frac{D^{3{\cdot}6}}{L^{1{\cdot}7}}$. $Y = \frac{wc}{w+\frac{2}{3}c}$.	Calculated breaking weight per sq. inch in tons.	Ratio of strength of pillars of same dimensions with *rounded* ends.
6	6	12		777 51	27·49	1·86
8	"	16		608·95	21·53	2·21
10	"	20		483·85	17·11	2·57
12	"	24		391·33	13·84	2·83
14	"	28	314·74		11·13	2 96
15	"	30	279·91		9·89	2·96
16	"	32	250 82		8·87	2·96
18	"	36	205·31		7·26	2·96
20	"	40	171·63		6·07	2·96
12	7	20 4-7		631·71	16·41	2·62
16	"	27 3-7	436·88		11·35	2·96
20	"	34 2-7	298·95		7·76	2·96
12	8	18		946·16	18·82	2·43
16	"	24		681·43	13·55	2·85
20	"	30	483·49		9·61	2·96
12	9	16		1339·12	21·04	2·25
16	"	21 1-3		984·79	15·47	2·70
20	"	26 2-3	738·82		11·61	2·96
16	10	19 2		1360·13	17·31	2·55
20	"	24		1047·62	13·33	2·87
16	11	17 5-11		1811·41	19 06	2·41
20	"	21 9-11		1413·07	14·86	2·75
16	12	16		2341·62	20·70	2·28
20	"	20		1849 02	16·34	2·63

Solid Square Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Number of diameters contained in the length or height.	Cubical content in feet.	Approximate weight of pillar in lbs.	Calculated breaking weight in tons from formula, $W = 10{\cdot}95\frac{D^4}{L^2}$.	Calculated breaking weight in tons from formulæ, $W = 10{\cdot}95\frac{D^4}{L^2}$. $Y = \frac{wc}{w+\frac{2}{3}c}$.
18	8	27	7·999	377·39		100·54
19	"	28 5	8·443	398·36		94·65
20	"	30	8·888	419·32		89·15
21	"	31·5	9 332	440·29		84·01
22	"	33	9·776	461·26		79·22
23	"	34·5	10·221	482 22		74·77
24	"	36	10 665	503·19		70 62
25	"	37·5	11·110	524·16		66·78
26	"	39	11·554	545·12		63·15
27	"	40·5	11·998	566·09		59·81
28	"	42	12·443	587·05		56·69
29	"	43 5	12 887	608·02	53·33	
30	"	45	13·332	628·99	49·83	

Solid Square Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Number of diameters contained in the length or height.	Cubical content in feet.	Approximate weight of pillar in lbs.	Calculated breaking weight in tons from formula, $w = 7{\cdot}81\frac{D^4}{L^2}$.	Calculated breaking weight in tons from formula, $w = 7{\cdot}81\frac{D^4}{L^2}$, $r = \frac{w\,c}{w + \frac{2}{3}c}$.
18	8	27	7·999	348·36		77·45
19	"	28·5	8·443	367·71		72·57
20	"	30	8·888	387·07		68·05
21	"	31·5	9·332	406·42		63·87
22	"	33	9·776	425·77		60·01
23	"	34·5	10·221	445·13		56·44
24	"	36	10·665	464·48		53·13
25	"	37·5	11·110	483·84		50·05
26	"	39	11·554	503·19		47·24
27	"	40·5	11·998	522·54	43·88	
28	"	42	12·443	541·90	40·80	
29	"	43·5	12·887	561·25	38·03	
30	"	45	13·332	580·60	35·54	

(To be Continued.)

ERRATA.—In the January number, page 42, first table at top of page—Table showing one-tenth of the breaking weight in tons—diam. 7 ins., height 12 ft., weight 63·91 tons, read weight 59·15 tons. Second table from top—Table showing one-fourth of the breaking weight in tons—diam. 7 ins., height 12 ft., weight 159·79 tons, read weight 147·88 tons. Fourth table from top—Solid uniform cylindrical pillars, &c.,—height 12 ft., diam. 7 ins., breaking weight 639·16 tons, read breaking weight 591·52 tons.

Improvement in Telegraph Cables.—Specification of the Patent granted to THOMAS WILLIAM EVANS, M. D., of the City of Paris, France, for Improvements in Telegraphic Cables.—Dated March 7, 1861.

From the Repertory of Patent Inventions, Jan., 1862.

In constructing electric telegraph cables, I employ a conductor composed of several wires drawn from metal rendered absolutely pure by a process analogous to that employed in the refining of the precious metals, or by any other process of refining. As copper possesses nearly seven times greater electrical conductibility than iron, I adopt copper as the constituent metal of the wire conductor. By the increase of purity, the tenacity, and consequently the conductibility, of the wire, is largely augmented. Recognising the well known electrical law, that the capacity of condensation is in exact ratio with the superficial surface of the conductor, and impressed with the serious risk involved in the employment of a submarine electric conductor composed of only a single wire, I combine seven copper wires (drawn from perfectly pure metal) six of which surround the remaining one as a centre. Having first placed these wires in parallel lines in close contact with each other, I draw them altogether through a round-holed draw plate. By this means I reduce the volume, and compel the wires to assume the form of longitudinal sections of a prolonged cylinder, the

exposed surface of which will be of course exactly equal to that of a single wire of the same diameter, while additional strength and additional safety from risk of total rupture are effectually secured by the use of independent wires. Upon the cylindrical conductor thus prepared I superimpose, to guard against the possibility of any defects in the metal, by means of a galvanic battery, and a bath containing either copper or gold in solution, a slight coating or plating of pure copper or gold (the latter I prefer). By thus presenting a surface of absolutely pure metal, the facility of electrical transmission is sensibly increased, whilst the danger of any chemical action upon the conductor from the contact of the insulation is entirely avoided.

It is a well known fact that when caoutchouc, vulcanized in the ordinary manner with heat, is applied in direct contact with the copper, a chemical effect is produced on the metal, which is rapidly corroded and rendered brittle. It has been attempted to avoid this action by coating the wire with tin and silk or cotton, but the tin is also corroded, and the silk or cotton by capillary attraction absorbs the sulphur, thus communicating it to the wire; now pure caoutchouc over a gold surface has no such effect. For insulating the conductors of electric telegraph cables, I employ three distinct coats, an interior one of pure caoutchouc, a second of gutta percha, and a third of caoutchouc.

Regarding the total exclusion of air as a matter of absolute necessity to the effectual working of submarine cables in great sea depths, I effectually secure this important result by a simple and beautiful adaptation of forces existing in nature. For the interior coat I employ pure caoutchouc unmixed with any other material. From thin sheets of india-rubber I cut long narrow bands, which are then united end to end, and stretch to such a degree as to lose their elasticity; this inelastic gum cord is then wound upon bobbins, and from these bobbins it is rolled off by simple machinery upon the metallic wire conductor, already prepared in the same manner that the large brass strings of musical instruments or ordinary insulated wire employed in electromagnetic batteries are manufactured. Over this a second coating of gutta percha in a semi-liquid state is imposed, and upon this is placed a third coating of caoutchouc, either pure or combined with pulverized glass, feldspar, sand, or other non-conducting substances. This is vulcanized by passing it through a bath of sulphide of carbon, or the cold process of vulcanizing. When these three insulating coats have been placed in the manner above mentioned, the conductor, thus coated, is passed through a chamber heated to a gentle heat, and by this means the following results are obtained:—The gutta percha gradually softens and forms a complete solder between the two coats of caoutchouc, whilst at the same moment the inner coating of spun caoutchouc, which when cold remains in its inelastic state, endeavors to assume its normal contracted condition before being subjected to stretching. It consequently, by the nature of its being, swells largely, and thus determines an enormous and continued pressure upon the wire conductor. Thus two important results are attained, namely, the solid union of all the coats of the insulation, and the total exclusion

of air. A conductor thus insulated I cover with an external envelope of hemp or other fibrous material wrought in the usual fashion of ships cordage.

By the combination I can let the wires run together in parallel lines to save bulk, and then let one or more branch off to different stations. It is especially useful for telegraph lines passing over the tops of houses. The combined wires being so compact they make an economy of the outer covering, be it what it may, as there is no loss of substance in the interstices between the wires.

I claim the constructing the conductors of electric telegraph cables by combining several wires together, as herein described, not only for submarine, but also for ordinary telegraphs.

I also claim the covering the wire conductors with gold, both in constructing submarine and ordinary telegraph cables.

And I also claim the insulating the conductors of electric telegraphic cables as herein described.

Silvering Glass and other surfaces.—Specification of the Patent granted to JOHN CIMEG, of the County of Middlesex, England, for Improvements in Silvering Glass and other surfaces.—Dated March 13, 1861.

From the Repertory of Patent Inventions, Jan., 1862.

This invention has for its object improvements in silvering glass, and other surfaces. For this purpose I employ a mixture of ammonia, nitrate of silver, with a solution of Rochelle salt (tartrate of potash and soda); this mixture is applied to the surface of glass to be silvered, and after a short time the silver is deposited on the glass as a bright film. The silver is deposited at the ordinary temperature of the air; thus it is not necessary to heat the surface, as when other mixtures are employed. The film of silver may be strengthened by depositing over it a cheaper metal, such as copper. The process above described is also applicable for silvering other surfaces; it is, for example, very useful for giving a metallic and conducting surface to articles on to which it is desired to deposit copper by electricity, and where the article itself is not a conductor of electricity.

In order to silver the surface of paper, or of a woven fabric, or other similar surface, I first deposit the silver on to a polished surface, such as glass; then attach the fabric thereto by suitable cement, and carefully strip the fabric, together with the silver, from the polished surface. In some cases, I obtain an ornamental effect by depositing the silver on a surface on which a pattern has been produced by dulling a portion of the surface.

And in order that my said invention may be most fully understood and readily carried into effect, I will proceed to describe minutely the manner in which I prefer in practice to conduct the processes.

In order to silver a sheet of glass, I place the said sheet, previously washed clean with water, on a table, and rub the whole surface of the sheet with a rubber of cotton or other soft fabric wetted with distilled

water, and afterwards with a weak solution of Rochelle salt in distilled water, about one part of salt in 200 parts of water. I then take a solution, previously prepared by adding nitrate of silver to ammonia of commerce; the nitrate of silver being very gradually added until a brown precipitate commences to be produced, and the solution is then filtered.

For each square yard of glass to be silvered, I take as much of the above solution as contains twenty grammes (about 309 grains) of nitrate of silver, and to this I add as much of a solution of Rochelle salt in distilled water as contains fourteen grammes of salt, and the strength of this latter solution should be so adjusted to that of the silver solution that the total weight of the mixture of the two in the quantities above mentioned, may be sixty grammes. In a minute or two after the mixture is made, it begins to become turbid, and it is then immediately to be poured over the surface of the glass, which has previously been placed on a perfectly horizontal table, but the plate is blocked up at one end, so as to give it an inclination of about one in forty; the liquid is poured on to the plate, along the higher edge, and it runs towards the lower; the pouring is done in such a manner as to distribute the liquid over the whole surface of the plate, without allowing any to escape at the edges. When this is effected, the plate is placed in a horizontal position, at a temperature of about sixty-eight degrees Fahrenheit. The silver will begin to appear in about two minutes. Before the end of ten minutes the plate will be covered, and in thirty minutes sufficient silver will be deposited; this is about two grammes of silver per square yard, which is enough for most purposes. The mixture is then poured off the plate, and the silver it contains is afterwards recovered. The silvered surface of the glass is then washed by pouring water over it four or five times, and the plate is set up to drain and dry. When dry, the silvered surface is varnished by pouring over it (in the same way as the mixture is poured on, as already described) a varnish, composed of the following materials, viz:—

Gum damar,	20 parts.
Asphalte (bitumen of Judea),	5 "
Gutta percha,	5 "
Benzine,	75 "

This varnish dries and sets hard on the surface, and the glass is then ready for framing, or otherwise for use as may be required. When a surface of glass has been silvered as above described, a layer of copper may be deposited over the silver by the ordinary electrotype process, or otherwise, as is well understood. I do not, however, prefer to do this when the object is to obtain a silvered glass, but in some cases I deposit a considerable thickness of copper on to the silver, and then strip the copper and silver together from the glass, which will be done with facility when the coating of copper is thick. In this manner a sheet of any size of plated copper may be produced, plates of other non-absorbent materials (which will not act chemically on the silver solution) may be coated with silver in the same manner as plates of

glass. When it is desired to give a metallic and conducting surface to an article which it is desired to electrotype, say, for example, a medallion of wax or gutta percha, I silver it as already described, sufficient of the silvering mixture being employed to cover every part of the surface. In order to silver paper, woven fabrics, and other materials according to my invention, I, as already mentioned, strip the silver from the surface on which it is deposited by attaching to it the paper, woven fabric, or other similar material, and then removing the said material and the silver film together from the surface. The silver is first deposited, by preference as already described, but it may be otherwise, on to a surface, by preference of glass, then on to the silvered surface is poured in the manner already set out a varnish consisting of gum lac dissolved in wood spirit, one part of gum lac to from six to ten of wood spirit. When this varnish is dry and hard, a solution of one part of gelatine in from six to ten of water is also poured over, and allowed to set into a jelly; the paper, leather, or woven fabric, or other similar material to be silvered, is laid on and pressed in contact with the jelly, and it is then left to dry thoroughly; afterwards the material with the fabric is stripped from the surface, and the process is complete.

On the Carburation of Gas.

From the Lond. Chemical News, No. 105.

The following report has been addressed to the Commissioners of Sewers of the City of London, by their Engineer, Mr. W. Haywood.

"In pursuance of the resolution of the Court of the 23d of April last, I have directed an experiment with the view of testing the value of the application to the public lamps, of the process patented by the United Kingdom Carburating Gas Company.

"The patent of this Company is for placing near to the gas burners a receptacle containing coal naphtha; the gas passing through or over this takes up, and becomes enriched by the addition of the volatile hydro-carbons contained in the naphtha, and the illuminating power of the gas is thereby increased; the quality of the naphtha employed determines mainly the degree of illuminating power gained, and the chemical and photometrical experiments laid before me show that it varies from 25 per cent. to 77 per cent. (See Appendix.)

"The experiment being one in which the gas companies are much interested, I applied to the Chartered Company, who light Moorgate Street, suggesting their co-operation in conducting it with me; the suggestion was at once acceded to, and their Inspector, Mr. Johnson, was placed in communication with me for that purpose.

"Moorgate Street was selected as being well adapted for the experiment, there being an equal number of lamps upon each side of the way, but one or two private lamps only in the street, and but few shops; the street is, therefore, after an early hour of the evening, almost entirely without artificial light, excepting that which it derives from the public gas-lights.

"The patentees stating that, by the application of their process, equal light would be given with half the ordinary consumption of gas, the burners were regulated accordingly.

"The lamps experimented upon were twelve in number, six upon the western side, which were fitted with the ordinary bats-wing burners, calculated to consume upon the average of the night, 5 cubic feet of gas per hour, and six upon the eastern side, fitted with bats-wing burners, calculated to consume 2½ cubic feet per hour. The latter burners having attached to them the carburating apparatus of the Company, each of the twelve burners had a metre attached to it, to ascertain the actual consumption. No pressure regulators were fixed upon the lamps.

"The registration commenced upon the 19th of June, and terminated upon the 19th of July inst., the experiment extending therefore over thirty nights, and gave the following results:—

"That the burners without the carburating apparatus consumed about 4·39 cubic feet per hour.

"That the burners fitted up with the carburating apparatus consumed 2·09 cubic feet per hour.

"No photometer was employed, the equalization of the amount of light given by the two classes of burners was a matter of judgment. The District Inspector of the Commission who saw the lights nightly, reports his opinion that the light given was perfectly equal, and that his opinion is strengthened by collecting those of certain residents in the neighborhood. My own opinion is that the light of the 2½ feet burners was upon the average of the month inferior, although but very slightly so, to that of the 5 feet burners. The Inspector of the Chartered Company coincides with me in this.

"No chemical analysis was made of the naphtha used; but it is stated by the patentees to have been of the best quality.

"My deduction from the experiment is, that with naphtha of equal quality to that used, during the warm months of the year 3 cubic feet of carburated gas may be considered as about equal to 5 cubic feet of gas not carburated.

"Assuming this to be data applicable to all seasons of the year, I have estimated the saving to be effected by the process, and, after allowing for the cost of the apparatus, and for periodically filling it with naphtha, and, after giving credit at the present price of the gas supplied to the public lamps for the quantity not consumed, it shows that the reduction in the cost of each public lamp will be at least £1 per annum; and there being 2825 lamps within the City, that a saving of £2825 would be annually effected.

"The only disadvantage observed during the experiment, was that the reservoir, as constructed, throws a disk of shadow round the base of the gas-lamp standard, but the depth of shadow is but slight; this disadvantage may be largely rectified by an alteration in the form of apparatus.

"It should be understood that I do not pledge myself to any of these figures as exact, for the experiment as conducted cannot lay

claim to be minute or exact in its character; but I believe it may, nevertheless, be taken as giving a close approximation to the truth; it is the mean of the rough results of practice, and the refined processes of the laboratory, from which reliable data are generally drawn; in this case, the results of the experiment are supported by laboratory experiments, and consequently there seems but little doubt that this mode of applying naphtha to the public lights (for the naphthalization of gas itself is by no means new) may lead to a considerable reduction in the cost of public lighting; but what that reduction ultimately would be, would depend upon points which can only be determined by the application of the process to a considerable number of lamps for some length of time, and at different seasons."

The following is Dr. Letheby's Appendix to the above report:—

"The apparatus consists of a chamber for holding coal naphtha, and of a contrivance for directing the stream of gas over the surface of the naphtha. By this means, the gas becomes charged with volatile hydro-carbons, and acquires a higher illuminating power.

"Three sets of experiments were made for the purpose of determining the value of the apparatus. In the first set, a naphtha rich in benzole was employed, and the results were, that at first it raised the illuminating power of ordinary twelve-candle gas to twenty-four candles, and in the course of three days the power fell to eighteen candles, the mean of the whole being twenty-one candles. This is an increase of 77 per cent., and it was effected by giving 10·77 grains of naphtha to each cubic foot of gas.

"In both of the other sets of experiments, an inferior kind of naphtha was used, and, in one case, the average increase of illuminating power, during a period of ten days, and after the passage of a thousand cubic feet of gas, was 25 per cent. In the other case, after a duration of five days, the average increase was 30 per cent. The former was effected by the addition of four grains of naphtha vapor to each cubic foot of gas, and the latter by 6·56 grains.

"These data are sufficient to indicate the general capabilities of the apparatus; for they show that with a good naphtha, supplied in proper quantity, and furnishing from ten to eleven grains of vapor to each cubic foot of gas, the illuminating power of an inferior gas may be nearly doubled. A less volatile naphtha, giving only from four to seven grains of vapor per cubic foot, will increase the power of twelve-candle gas from 25 to 30 per cent. I am, therefore, of opinion, that the apparatus is of practical value as a carburetting agent, and that, if supplied with good naphtha in proper quantity, there will be no difficulty in sustaining a power of twenty candles with ordinary coal gas."

Upon receiving this Report and Appendix, the Commissioners of Sewers resolved that it should be referred to the Engineer and Medical Officer of Health, to consider the conditions of the contracts for public lighting; having special reference to the increased illuminating

power of the gas to be supplied, and to the possibility of carburating the gas by the process of the Carburating Company.

These gentlemen, Dr. Letheby and Mr. Haywood, have now reported upon this subject in the following terms:—

"Before considering the general conditions of a contract, it is necessary first to obtain the determination of your honorable Board to the leading principles upon which the contract should be framed, and it is to those we now specially address ourselves.

"As regards that portion of the reference which relates to the possible reduction of the consumption of gas in the street lamps, we are of opinion that, if the carburating process is not applied, the increase of the illuminating power proposed by the Metropolis Gas Act of 1861, does not render it expedient to diminish the amount of gas to be supplied at the burners of the public lamps; and that the contract should therefore remain as heretofore in this respect, unless the Companies alter the quality of the present supply, and furnish Cannel gas to the public lamps, as the Act of Parliament empowers them to do: under which circumstances it will be necessary to re-adjust the contract and mode of supply accordingly.

"With regard to the carburating process, we are of opinion, from the data obtained by the laboratory experiments quoted in the report to the Commission of the 30th July last, and the experiments made on the public lamps in Moorgate Street, during the months of June and July last, that the process of carburation appears to be capable of economizing the use of gas in the public lamps, to the extent of from 40 to 50 per cent. This conclusion is founded on the assumption that the best quality of naphtha is to be used, namely, a naphtha which will give to the gas continuously a proportion of about ten grains of volatile hydro-carbon to each cubic foot of gas: these being the average results of the laboratory experiments. If an inferior kind of naphtha be employed, the results will be less satisfactory; for the laboratory experiments show that a naphtha yielding four grains of volatile hydro-carbon will increase the illuminating power of the gas only to about from 15 to 20 per cent.

"It is manifest, therefore, that the practical efficacy of these results will be entirely dependent on the perfection of the apparatus and the quality of the naphtha, and we are of opinion that these essential conditions can only be secured during the earlier application of the process by an arrangement with the Carburating Company for the supply of the apparatus and the naphtha, as also for the maintenance of the same in complete working order, according to the terms of a contract founded on the preceding data, namely, that a burner consuming three feet of the naphthalized gas per hour, shall give continuously the light of a burner consuming five feet per hour of the same gas not naphthalized; and to secure this, the naphtha should be of such quality as to furnish continuously not less than seven grains of volatile hydro-carbon to each cubic foot of the gas. If the company is willing to undertake such a contract upon suitable terms, we see no difficulty in the practical application of the system.

"If these suggestions are adopted, it will be necessary to contract both with the Gas Companies and the Carburating Company; the terms of such contracts, which should have due relation to each other, must be a matter for future consideration."

Bath for High Temperatures. By EMERSON REYNOLDS.

From the London Chemical News, No. 106.

Some time ago, having occasion to use a bath capable of affording a temperature considerably above that of boiling water, my friend Mr. Tichborne suggested to me the use of glycerine instead of the ordinary saline baths. I tried a mixture of glycerine and water, and found it to answer so well the purpose for which it was intended, that I thought it would be worth while to make known a few particulars which might prove useful to chemists.

I found the boiling-point of a mixture of six parts water with one part glycerine (by measure), to be about 218° F.; with equal parts glycerine and water, 230°; and by using six parts glycerine with two of water, the temperature was raised to and remained steady at 250°. If the proportion of glycerine be much increased beyond this point, acrid fumes are given off on heating the mixture.

The glycerine which I used in these experiments, though otherwise pure, had frequently been accidentally exposed to the air, and had, doubtless, absorbed some moisture from the atmosphere; therefore, the results given above may be looked upon as correct for the mixtures experimented upon, though perhaps they may not hold good when other samples of glycerine are used.

Weisbach's Formula for Finding the Head due to the Friction of Water in Pipes.

From the Civ. Eng. and Arch. Jour., Dec., 1861.

SIR:—I perceive at page 341 of your *Journal* for November, in an extract from Fairbairn's book on Mills and Mill-work, a reference to Weisbach's formula for finding the head due to the friction of water in pipes when the velocity is known. This formula as given by you, from Mr. Fairbairn, is

$$h_1 = \left(\cdot 01482 + \frac{\cdot 017963}{\sqrt{v}}\right)\frac{l}{d} \times \frac{v^2}{2g}:$$

I beg to say, the correct reduction of Weisbach's formula to English feet measures, is

$$h_1 = \left(\cdot 0144 + \frac{\cdot 01716}{\sqrt{v}}\right)\frac{l}{d} \times \frac{v^2}{2g};$$

and I can speak from experience that it can be depended upon for giving practically correct results. It has, however, for use a very great disadvantage, namely, that it is not possible to solve it directly for v, so as to find the value of the velocity in terms of length, dia-

meter, and fall of the pipe; and as this is what is most generally required, this formula loses much of its value as a practical rule for ready application without tables. It is evident to me that Mr. Neville's general, yet simple formula, page 217, 2d edition of his book,* and

$$v = 140\sqrt{r\,s} - 11\,(r\,s)^{\frac{1}{3}},$$

also as given in your *Journal*, vol. xv., p. 353, in which $s = \frac{h}{c}$ and $r = \frac{d}{4}$, remedies this defect, and the results I have found, for ranges of velocity between 6 inches and 16 feet, in all descriptions of uniform long channels, to be more correct than those found from any other formula I had occasion to calculate from. Mr. Fairbairn must have taken the reduction of Weisbach's formula from vol. i., p. 431, of the English translation of Weisbach's book,† and it differs equally from the reduction by Prof. James Thomson, Belfast, in Weale's Engineer's Pocket-book, and that given by Mr. Neville, p. 213, 2d edition of his valuable book. I have carefully gone over every formula for finding the flow through long uniform channels. Neville's, Weisbach's, and Du Buat's, are unquestionably the best. Young's, Eytelwein's, and Prony's, are only accurate within very limited ranges of velocity, and all others are but modifications of these last, suited to different standards of measurement, and equally limited to their application.

I am, Sir, your obedient servant,

AN OBSERVER.

[It was pointed out in the review above referred to, that Weisbach's formula was repeated at the foot of the tables with rather smaller constants than in the text. Our correspondent gives the formula as it is given under Mr. Fairbairn's tables.—ED. C. E. & A. J.

*Weale, 59 High Holborn, London. †Bailliere, 219 Regent Street, London.

On the Form and Materials for Iron-Plated Ships, and the Points requiring attention in their Construction. By Mr. JOSEPH D'A. SAMUDA.

From the Lond. Mechanics' Magazine, January, 1862.

The author stated that, iron-plated ships having now become a necessity, it was important to ascertain, first, the best description of construction of ship and armor, and secondly, the best form and dimensions of vessel.

To effect these objects, there were four indispensable conditions:—first, these vessels must be of such dimensions and power, and be built on such lines, that they should always command a superiority in speed over the best timber-built frigates afloat; secondly, they must be protected with armor over their entire length; thirdly, the armor must be so applied as to be capable of rapid replacement, or repair; and fourthly, the armor should enter into the construction of the ship, and thus give strength to the whole fabric, as well as protect it from an enemy's fire.

These conditions had only been partially attained in the vessels already constructed, or proposed to be constructed; for the *Warrior* class obtained speed alone, the *Defence* class failed in all, the *Valiant* class only approached the second condition, and the three new ships of 6700 tons burthen, recently contracted for at a cost with their engines of £400,000 each, would probably possess the first and second, but not the third and fourth conditions.

Although the *Warrior* was highly creditable as a first effort, and was not defective in strength, yet it was a complicated and costly construction, and its character should not, therefore, become stereotyped, as incapable of further improvement, or as if it were not desirable to seek for it.

The author proposed that the framework of the hull should be built as in an ordinary first-class steamer of the same size; and that, outside the framework, and riveted to it, there should be five longitudinal ribs, at intervals of 5 feet, reaching 20 feet below the gunwale. These longitudinal ribs should be of bars of rolled iron, 2½ inches in thickness, and 16 inches wide, the outer 4 inches on each side being recessed 1 inch. The ordinary skin plates, 1 inch thick, were then riveted in these recesses, so as to form a flat surface for the reception of the armor, each strake of which was to be made to correspond with the distance from centre to centre of the longitudinal ribs. The edges of the armor plates, 5 inches in thickness, were then to be bolted or riveted through the ribs longitudinally, the vertical butt-joints of each plate, made to break joint with the skin plates, being riveted to corresponding ribs, 2½ inches in thickness, placed between the longitudinal ribs, and attached to them with fish-plates. It had been determined by experiment that this thickness of rib would be sufficient to render the edges of the armor plates, when weakened by the rivet holes, equal in strength to the central body of the plates. By this arrangement, a perfect ship, without armor, was first made; then a complete armor case was attached through the longitudinal ribs, without interfering with the joints, or fastenings of the ordinary skin of the vessel. Indeed, the skin would be so distinct from the armor that, in time of peace, the armor could be removed, and the vessel be used as a transport, if desired. By these means, the armor could be rapidly repaired at any point, and there would be no necessity for tongueing and grooving the plates, adopted as an expedient by the Admiralty to remedy the bending up at the edges, which the present imperfect mode of fastening rendered them liable to.

Thus, protection would be obtained over the entire length of the vessel, by the armor admitting of rapid replacement, and entering into the construction of the ship. It remained only to show what dimensions and power were necessary to secure speed. For a 32-gun frigate, constructed as described, the best dimensions would be 382 feet long, 55 feet beam, and 31½ feet deep to the main deck; 5600 tons burthen, and fitted with engines of 1200 H. P., by which a speed of 15 knots an hour could be obtained, with the armament, ammunition, and coal on board, and with the port sills 9 feet above the water

line. Such a vessel would have even greater speed than the *Warrior*, and be wholly protected over the entire length of the sides.

As the importance of complete protection had now been recognised by the Admiralty, it was desirable to compare this armor-skin vessel, of 5600 tons burthen, with those now building. The Admiralty vessels were to be 6700 tons burthen, and 1250 H. P., but they would not be able to carry a heavier armament, or possess a higher speed than the proposed vessel; they would be less manageable, form larger objects to fire at, and cost £400,000 each instead of £340,000, or, in a fleet of twenty-four such frigates, one million and a half pounds sterling more.

For coast defences, vessels might be built, protected from stem to stern, having a length of 200 feet, beam of 48½ feet, depth of 25 feet, burthen of 2200 tons, and engines of 350 H. P., pierced for thirty-two 68-pounder guns, but carrying only sixteen, with a draft of water of 16 feet, when the guns, ammunition, and coal, were on board, and capable of attaining a speed of 11 knots an hour.

In conclusion, the author thought that the time had arrived, when the Admiralty should see the propriety and the advantage to the public service of abandoning the monopoly of restricting all advance in the construction of mail-clad vessels to plans and systems emanating from themselves; and that it would be far better to trust to the engineering skill of this country, leaving it free to take the initiative in improving this branch of national defence, and the Admiralty only exercising a veto within such limits as experience fitted them to form a judgment upon.

It was announced that the discussion upon Mr. Samuda's paper "On Iron-Plated Ships," which was commenced, would be resumed at the next meeting, Tuesday, February 4th.

Institution of Civil Engineers, Jan. 28th, 1862.

On White Gunpowder. By F. Hudson, Esq.

From the London Chemical News, No. 90.

Having lately prepared different samples of white gunpowder (according to the receipt of Dr. J. J. Pohl, given in the *Chemical News*, July 6) for some military engineering experiments, I have tried the process of separately grinding the materials, viz: chlorate of potash, ferrocyanide of potassium, and cane sugar, and then mixing them; also grinding them together with a little water added, and then dried at a temperature of about 150°. I find that those samples which were prepared moist and then dried, are more easily exploded than those prepared by the dry process. In fact, one sample exploded in an open porcelain dish, by simple friction with a spatula with which one of my assistants was crushing some of the larger pieces. Through the explosion, he was laid up for several weeks, and nearly lost his eyesight. No samples prepared dry are as explosive as those prepared moist, the addition of water causing a more perfect mixture of the particles

of its chemical constituents than can be effected by the dry grinding process. This accounts for the greater danger attending the use of white gunpowder prepared in the moist way.

A cannon loaded with the white powder goes off on the application of a few drops of sulphuric acid (equally as well as with a light applied) to its touch-hole.

This property of the gunpowder may possibly be applied to some advantage in the construction and preparation of bomb-shells for long ranges. The shells would not explode (if filled with the white powder, and containing a glass vessel with sulphuric acid) until they struck the object. No useless explosion of the shell could take place in the air, as is too often the case with the ordinary fusee shell.

Its expansive or explosive force is also twice that of common gunpowder. In all experiments performed with this white gunpowder, care must be taken not to compress it too violently; otherwise accidents may frequently occur. A blow with a hammer upon stone with some of the powder upon it, explodes all samples that I have prepared.

On the Manufacture of Cast Steel, and its Application to Constructive Purposes. By Mr. Henry Bessemer, of London.

From Newton's London Journal, February, 1862.

The mode of manufacturing cast steel, which now forms so important a branch of the Sheffield trade, was discovered in the year 1740 by Mr. Benjamin Huntsman, of Handsworth, near Sheffield, who subsequently established steel works at Attercliffe, where his invention has ever since been successfully carried on. In its early stages many difficulties had, however, to be overcome. Materials for lining the furnaces and for making the crucibles had to be sought for and tested; the peculiar marks of iron most suitable for melting had to be determined on by numerous experimental trials; and such was the difficulty at that time of making crucibles which would stand the excessive heat of melted steel, that for a long period only very highly carbonized or "double converted" steel, which required the lowest temperature, could be successfully melted. The first products of a new manufacture, even while the invention still remains in a partially developed state, but too frequently stamp its subsequent character. Thus Huntsman's cast steel, although it was acknowledged to be a pure homogeneous metal, of great value for certain purposes, was still looked upon as a hard and brittle material of very limited use, not bearing a high temperature without falling to pieces, and quite incapable of being welded: even within the last few years this has been the popular idea of cast steel. Improvements in its manufacture have, however, from time to time been introduced, and steel of a milder and less brittle character has long been made, capable of welding with facility, and working at a high temperature without falling to pieces. Its uses have consequently been greatly extended, and the employment of cast steel for the best cutlery and edge-tools has now become universal; indeed,

the excellent quality of the cast steel at present made in Sheffield for these purposes is scarcely to be surpassed. Of late years several of the most enterprising manufacturers have sought to introduce cast steel for a variety of other purposes besides those for which it was originally employed, and it is now used, in some form or other, in almost every first-class machine. Its employment as a material for founding bells and various other articles in clay moulds, as carried out by Messrs. Naylor and Vickers, and the introduction of a valuable material by Messrs. Howell and Shortridge, under the name of homogeneous metal, are prominent examples of the successful adaptation of cast steel to engineering purposes.

The manufacture of cast steel by Huntsman's process is so extensively practised, and is so well known, that it is unnecessary to do more than to recall to mind that crude pig iron has first to go through all the stages of melting, refining, puddling, hammering, and rolling, in order to produce a bar of malleable iron as nearly pure as the most careful manipulation in charcoal fires can make it. Bar iron, on which so much labor, fuel, and engine power have been expended, thus becomes the raw material of this most expensive manufacture. In order to convert the wrought iron bars into blister steel, they are packed with powdered charcoal in large fire-brick chests, and are exposed to a white heat for several days, the time required for heating and cooling them extending over a period of fifteen to twenty days. When thus converted into blister steel, they are broken into small pieces and sorted, according to the quality of the steel, which sometimes differs even in the same bar. For melting this material, powerful air furnaces are employed, containing two crucibles, into each of which are put about 40 lbs. of the broken blistered steel. In about three hours the pots are removed from the furnaces, and the melted steel is poured into iron moulds, and formed into ingots of cast steel; from 3½ to 4 tons of hard coke being consumed for each ton of metal thus melted. When large masses of steel are required, a great many crucibles must be got ready all at the same moment, and a continuous stream of the melted metal from the several crucibles must be kept up until the ingot is completed, since any cessation of the pouring would entirely spoil it; hence, in proportion to the size of the ingot, are the cost and risk of its production increased. The ordinary manufacture of cast steel is therefore obviously conducted at a great disadvantage. If cast steel is to supersede wrought iron for engineering purposes, it will be necessary to cease employing wrought iron as a raw material for this otherwise most expensive mode of manufacture.

The extremely high temperature requisite to maintain malleable iron in a state of fusion, has, from the earliest period of the history of iron down almost to the present day, rendered its purification in a fluid state practically and commercially impossible. Hence arise all those imperfections to which bar iron is subject, every small piece consisting of numerous granules partially separated from each other by scoria, and every large mass being produced only by piling together small bars, with the inevitable result of increasing the former imperfections;

for no two pieces of iron can be brought to a welding heat without becoming coated with oxide; and when this coating is rendered fluid by welding sand, a fluid silicate of the oxide of iron is formed, covering the entire surface to be united. The heavy blows of the hammer or the pressure of the rolls may, and do, extrude the greater portion of this fluid extraneous matter, but it is never wholly removed from between the welded surfaces, and hence a portion of the cohesive force of the metal is lost at every such junction. When a bar of iron is nicked on one side and bent, the rending open of the pile clearly shows this want of perfect cohesion. Nor is this the only difficulty to be encountered; for in the production of large masses of wrought iron it is necessary to raise the temperature nearly to the fusing point, in order to render each additional piece sufficiently soft and plastic to become united to the bloom. This softening of the iron induces a molecular change in the structure of the metal: its natural tendency to crystallize is so powerfully assisted by the long continuance of the high temperature, that its whole structure undergoes a change; large and well defined crystals are formed almost independently of each other, and cohering so feebly to the other contiguous crystals, as in some cases to separate with as little force as would overcome the cohesion of ordinary cast iron.

In the substitution of cast steel for malleable iron, both these sources of difficulty are escaped; for the mass, whether of one ton or twenty tons weight, may be formed in a fluid state into a single block, wholly free from admixture of scoria, while it is perfectly and equally coherent at every part, and the forging of such a solid block of metal into shape is only the work of a few hours; and as there is no welding of separate pieces, it may be worked under the hammer at a temperature at which no molecular change will take place; the metal being far below its fusing point, and much too solid to undergo that destructive crystallization so common in large masses of wrought iron. Thus the difficulties and uncertainty attending the production of all large masses of wrought iron are wholly avoided in producing equally large masses of cast steel.

But, however desirable in the abstract it may be to employ cast steel as a substitute for malleable iron for engineering purposes, it must not be forgotten that there are several important conditions indispensable to its general use. First, the steel must be able to bear a good white heat without falling to pieces under the hammer, otherwise the process of shaping it will not only be expensive, but the partly-finished forging may be spoiled at any moment by being overheated. Secondly, the steel should be of such a tough character as to admit of being twisted or bent into almost any form in its cold state before fracture takes place, whether the force be applied as a gradual strain or by a sudden impact. Thirdly, it should have a tensile strength at least 50 per cent. greater than that of the best marks of English iron. Fourthly, it must especially be soft enough to turn well in the lathe, to bore easily, and to yield readily to the file and chisel, so as not to enhance its original cost by the difficulty of working it into the requi-

site forms. This last is most commercially and practically an important condition, and one which will in future greatly determine the extent of its use.

These desirable objects are believed by the author to be fully accomplished by his process of converting crude pig iron into cast steel at a single operation, forming the subject of the present paper. This process has now been in daily operation in Sheffield for the last two years at Messrs. John Brown & Co.'s Atlas Steel Works, Sheffield.

The crude pig iron chiefly used in this process has been the hot-blast hæmatite pig smelted with coke, which is melted in a reverberatory furnace, and is then run into a vessel, in which its conversion into steel is to be effected. The converting vessel is made of stout boiler plate, and lined with a powdered silicious stone found in the neighborhood of Sheffield below the coal, and known as "ganister." The rapid destruction of the lining of the converting vessel was one of the great difficulties met with in the early stages of the invention: the excessive temperature generated in the vessel, together with the solvent action of the fluid slags, was found to dissolve the best fire-brick so rapidly, that sometimes as much as two inches thickness would be lost from the lining of the vessel during the thirty minutes required to convert a single charge of iron into steel. The ganister now used, however, is not only much cheaper than fire-bricks, (costing only about 11*s.* per ton in the powdered state,) but it is also very durable. [A portion of the lining of the vessel was shown, which had stood ninety-six consecutive conversions before its removal.] The converting vessel is mounted on bearings which rest on stout iron standards, and by means of the gearing and handle it may be turned into any required position. It has an opening at top for filling and pouring out the metal, and in the bottom of the vessel are inserted seven fire-clay tuyeres, each having seven holes. The blast from the engine is conveyed through one of the bearings of the vessel into the tuyere box, at the bottom of the vessel, and enters the tuyeres at a pressure of about 14 lbs. per square inch, which is more than sufficient to prevent the fluid metal from entering the tuyeres.

Before commencing with the first charge of metal, the interior of the converting vessel is thoroughly heated by coke, with a blast through the tuyeres to urge the fire; when sufficiently heated, it is turned upside down, and all the unburnt coke falls out. The vessel being now turned to nearly a horizontal position, melted pig iron is run in from the furnace by the spout, the vessel being kept in such a position, during the time of filling, that the holes of the tuyeres will be above the surface of the metal. When the proper charge of iron has been run in, the blast is turned on, and the vessel is quickly moved up into a vertical position. The blast now rushes upwards into the fluid metal from each of the 49 holes of the tuyeres, producing a most violent agitation of the whole mass. The silicium, always present in greater or less quantities in pig iron, is first attacked, and unites readily with the oxygen of the air, producing silicic acid; at the same time, a small portion of the iron undergoes oxidation, and hence, a fluid silicate of

the oxide of iron is formed—a little carbon being simultaneously burnt off. The heat is thus gradually increased until nearly the whole of the silicium is oxidized, which generally takes place in about twelve minutes from the commencement of the process. The carbon of the pig iron now begins to unite more freely with the oxygen of the air, producing at first a small flame, which rapidly increases, and in about three minutes from its first appearance a most intense combustion is going on: the metal rises higher and higher in the vessel, sometimes occupying more than double its former space, and in this frothy fluid state, it presents an enormous surface to the action of the air, which unites rapidly with the carbon contained in the crude iron, and produces a most intense combustion, the whole mass being, in fact, a perfect mixture of metal and fire. The carbon is now burnt off so rapidly as to produce a series of harmless explosions, throwing out the fluid slag in great quantities; while the combustion of the gases is so perfect, that a voluminous white flame rushes from the mouth of the vessel, illuminating the whole building, and indicating, to the practised eye, the precise condition of the metal inside. The blowing may thus be left off whenever the number of minutes, from the commencement and appearance of the flame, indicate the required quality of metal. This is the mode preferred in working the process in Sweden. But, at the works in Sheffield, it is preferred to continue blowing the metal beyond this stage, until the flame suddenly drops, which it does just on the approach of the metal to the condition of malleable iron: a small measured quantity of charcoal pig iron, containing a known proportion of carbon, is then added, and thus steel is produced of any desired degree of carburation; the process having occupied about twenty-eight minutes altogether from the commencement. The converting vessel is tipped forwards and the blast shut off for adding this small charge of pig iron; after which, the blast is turned on again for a few seconds.

The spout of the vessel is then depressed, and the fluid steel is run into the casting ladle, which is carried by a hydraulic crane, it being counterbalanced by a weight on the opposite end of the jib. When all the metal is poured out of the converting vessel, the crane is raised by water pressure and turned round, for the purpose of running the steel into the ingot moulds. Instead of tilting the casting ladle for pouring into the moulds, it is made with a hole in the bottom, fitted with a fireclay seating, and closed by a plug of fireclay forming a conical valve. The valve rod is coated with loam and bent over at the top, and works in guides on the outside of the ladle, with a handle for opening and closing the valve. By thus tapping the metal from below, no scoria or other floating impurities are allowed to run into the mould, and the stream of fluid steel is dropped straight down the centre of the mould right to the bottom, without coming in contact with the sides of the mould. The moulds are made of a slightly tapered form, so that as the ingot contracts in cooling, it liberates itself from the mould completely on all sides; and the mould is removed by being

lifted off the ingot when sufficiently set. The moulds are arranged in the moulding pit in an arc of the circle described by the casting ladle.

By this process from one to ten tons of crude iron may be converted into cast steel in thirty minutes, without employing any fuel except that required for melting the pig iron, and for the preliminary heating of the converting vessel; the process being effected entirely without manipulation. The loss on the weight of crude iron is from 14 to 18 per cent. with English iron worked in small quantities; but the result of working with a purer iron in Sweden has been carefully noted for two consecutive weeks, and the loss on the weight of fluid iron, tapped from the blast furnace, was ascertained to be only $8\frac{3}{4}$ per cent. The largest sized apparatus at present erected is that in use at the Atlas Steel Works, Sheffield, the converting vessel being capable of receiving four tons at a time, which it converts into cast steel in 28 minutes. In consequence of the increased size of the converting vessel, in this case, no metal is thrown out during conversion, and the loss of weight has fallen as low as 10 per cent., including the loss in melting the pig iron in the reverberatory furnace.

Specimens of this manufacture, as carried on at the author's works in Sheffield, were exhibited, consisting of a piece of the pig iron employed, which is No. 1 hot-blast hæmatite made with coke; also, a portion of an ingot of very mild cast steel, broken under the hammer to show the purity and soundness of the metal in its cast unhammered state; and an ingot, partly forged, to show how little work with the hammer will produce a forging from these solid blooms of steel. There were also two pieces of steel of the quality employed for making piston rods, which had been bent cold under a heavy steam hammer to show the toughness of the metal: it required very much more force to bend it than would be required to bend wrought iron, but, notwithstanding this additional rigidity, it will yield to any extent without snapping. The tensile strength of this soft and easily wrought metal is as much as forty tons per square inch, or from 15 to 18 tons greater than that of best Yorkshire iron. In turning, planing, boring, and tapping, it will be found that the uniformity of its quality will be less trying to the cutting tools than the hard reeds and sand cracks met with in the common qualities of malleable iron. The above tensile strength of the piston rod steel, however, is by no means the maximum, but, on the contrary, is nearly the minimum strength of the steel converted by this process; but, at the same time, it possesses nearly a maximum degree of toughness; for every additional ton in tensile strength, obtained by the addition of carbon, hardens the steel for working, renders it more difficult to forge, and brings it nearer to that undesirable state when a sudden blow snaps it like a piece of cast iron.

From tables compiled from experiments made at the Woolwich Arsenal, it appeared that after hammering or rolling, the steel or highly carbonized metal exhibits a mean tensile strength of 68 tons per square inch, but from its hardness and unyielding nature, it is totally unfit for many purposes; while the iron or entirely decarbonized metal is so soft and copper-like in its texture as to yield to a mean tensile

strain of 32 tons per square inch, a point unnecessarily low, except in cases where a metal approaching copper in softness is required. The soft, easy working, tough metal, of the quality used for piston rods, is therefore believed by the author to be the most appropriate material for general purposes; while the hard steels that range up to a tensile strain of 50 or 60 tons per square inch should be avoided as altogether too expensive to work, and too dangerous to be employed in any case where sudden strains may be brought upon them.

With reference to the employment of the mild cast steel for constructive purposes, there are few applications of more importance than that which has recently and successfully been made to the construction of steam boilers. The Cornish boiler, as improved by Mr. Adamson, of Hyde, near Manchester, has a large flue tube constructed with narrow plates more than 12 feet long, extending round the flue in one length, and flanched at each edge in a manner which, while it adds greatly to the stability of the flue, demands such qualities in the material employed for its manufacture as are completely found only in metal that has undergone fusion, and has become perfectly homogeneous throughout. A practical illustration of the excellence of this mode of constructing boilers and the powerful strains which the new steel is capable of sustaining safely, is afforded by the steam boilers employed for some time past at Messrs. Platt's works at Oldham, where six of these boilers are in daily use; they are 30 ft. long and 6½ ft. diameter, and the flue is 4 ft. diameter; the plates are $\frac{5}{16}$-inch thick, and the working pressure 100 lbs. per square inch.

The advantages of cast steel are still more marked in the construction of the fire-boxes of locomotive engines. The difficulty of flanching and shaping this work in plate iron without splitting the metal at some part, is so great as to have rendered the employment of copper necessary hitherto for this purpose; but the shape required can now be obtained with ease and certainty by hammering up a sheet of metal rolled from one of the cast ingots, such as that now exhibited. One of these fire-box plates, flanched by Mr. Anderson, is also shown, and clearly illustrates the facility with which the new metal may, under skilful hands, be wrought into any required form. The perfect continuity of the material and its entire freedom from joinings or weldings also obviously render it specially suitable for the tube plates of locomotive engines; for, however near the holes are made to one another, there is no danger of their having a flaw or other weak place between them. Nor is it in the construction of the boiler alone that the cast steel may be employed with advantage in locomotives: the axles, whether plain or cranked, the piston rods and guide bars, and last, but not least, the wheel tyres, are all exposed to so much abrasion, and to such sudden and powerful strains, that a tough strong material capable of withstanding this destructive wear and tear, is imperatively demanded for the satisfactory construction and economical working of the engine.

The special aim of the author during the first year of his labors, and which throughout the last six years has never been lost sight of, was

the production of a malleable metal peculiarly suitable for the manufacture of ordnance. By means of the process that has been described, solid blocks of malleable cast steel may be made of any required size, from 1 to 20 or 30 tons weight, with a degree of rapidity and cheapness previously unknown. The metal can also, with the utmost facility, be made of any amount of carburation and tensile strength that may be found most desirable. Commencing at the top of the scale with a quality of steel that is too hard to bore, and too brittle to use for ordnance, it can with ease and certainty be made to pass from that degree of hardness, by almost imperceptible gradations downwards, towards malleable iron; becoming at every stage of decarburation more easy to work and more and more tough and pliable, until it becomes at last pure decarbonized iron, possessing a copper-like degree of toughness not found in any iron produced by puddling. Between these extremes of temper the metal most suitable for ordnance must be found; and all qualities are equally cheap and easy of production.

From the practice now acquired in forging cast steel ordnance at the author's works in Sheffield, it has been found that the most satisfactory results are obtained with metal of the same soft description as that employed for making piston rods. With this degree of toughness the bursting of the gun becomes almost impossible; its power of resisting a tensile strain being at least fifteen tons per square inch greater than that of the best English bar iron. Every gun, before leaving the works, has a piece cut off the end, which is roughly forged into a bar of 2 inches by 3 inches section, and bent cold under the hammer, in order to show the state of the metal after forging. Several test bars cut from the ends of guns recently forged were exhibited.

The power of this metal to resist a sudden and powerful strain was well illustrated by a piece of a gun muzzle, which was one of several tubular pieces that were subjected to a sudden crushing force at the Royal Arsenal, Woolwich, under the direction of Col. Wilmot. The pieces were laid on the anvil block in a perfectly cold state, and were crushed flat by the falling of the steam hammer, but none of them exhibited any signs of fracture when so tested. Probably the best proof of the power of the metal to resist a sudden violent strain was afforded by some experiments made at Liège by order of the Belgian government, who had one of these guns bored for a 12 lbs. spherical shot of 4¾ inches diameter, and made so thin as to weigh only 9¼ cwts. This gun was fired with increasing charges of powder and an additional shot after each three discharges, until it reached a maximum of 6¾ lbs. of powder and eight shots of 12 lbs. each or 96 lbs. of shot, the shots being thus equal to about one-tenth of the weight of the gun. It stood this heavy charge twice, and then gave way about 40 inches from the muzzle, probably owing to the jamming of the shots. The employment of guns so excessively light, and charges so extremely heavy, would of course never be attempted in practice.

Some idea of the facility of this mode of making cast steel ordnance is afforded by the time occupied in the fabrication of an 18-pounder gun exhibited to the meeting. The melted pig iron was tapped from

the reverberatory furnace at 11·20 A. M., and converted into cast steel in 30 minutes; the ingot was cast in an iron mould 16 inches square by 4 feet long, and was forged while still hot from the casting operation. By this mode of treating the ingots, their central parts are sufficiently soft to receive the full effect of the hammer. At 7 P. M., the forging was completed, and the gun ready for the boring mill.

The erection of the necessary apparatus for the production of steel by this process, on a scale capable of converting from crude iron enough steel to make 40 of such gun blocks per day, will not exceed a cost of £5000, including the blast engine; hence the author cannot but feel that his labors in this direction have been crowned with entire success: the great rapidity of production, the cheapness of the material, and its strength and durability, all adapt it for the construction of every species of ordnance.

Proceedings Insti. Mech. Engineers, July 31, 1861.

Extraction of Butter. By M. J. A. BARRAD.

The time required for the formation of butter varies very much with the temperature. Near 54° Fahr., it requires ten times longer than at 68°. But when the temperature is too high, the yield of butter is much diminished. The best temperature for getting butter from milk is between 60 and 68°. The losses are much less when cream is churned in place of milk. The best temperature for getting the most butter from cream, and in the least time, too, is between 57 and 61°.

Cosmos.

Improvements in the Preparation of a Coloring Matter for Dyeing Textile Materials and Fabrics, and other Substances.—Patent of JOHN DALE.

From the London Chemical News, No. 54.

This patent appears to us to be both chemically and commercially important. The principle involved is simple enough, and merely consists in extracting the coloring matters of the dye-woods with alkaline solutions, and re-precipitating by means of acids. The coloring matters of barwood, camwood, redwood, &c., are, as is well known, soluble in alkalies, and the alkaline solutions are of a much darker and more intense color than the mere aqueous infusions. The alkaline solutions are, however, destitute of dyeing properties, and, moreover, any excess of alkali causes the coloring matter to undergo a chemical metamorphosis sufficient to permanently deprive it of tinctorial power. But by regulating the strength of the alkaline solution used as a solvent, the color may be extracted in its red condition, and free from the peculiar purple tint so familiar to all who have used logwood as the test in Dr. Price's improvement of Peligot's modification of Will's process for determining nitrogen. The patentee uses pressure in extracting, and pumps the boiling alkaline solution through the woods. 120 lbs.

of caustic alkali of 25 per cent., require 500 to 800 gallons of water for dilution before being sufficiently weak to prevent injury to the coloring matter. The patentee does not state from what weight of the different woods the above amount of fluid is capable of extracting the color. That the quantities vary greatly with the nature of the wood is, however, plain. The patentee states that camwood contains more acid than the other wood, and, consequently, requires more alkali.

On the Filtration of Air.

From the Lond. Edin and Dub. Phil. Mag., May, 1861.

As the result of a lengthened investigation on filtration of the air in reference to fermentation, putrefaction, and crystallization, Schrœder* is led to the following conclusions:—

1. A vegetable or animal can only be formed from having vegetable or animal organisms. *Omne vivum ex vivo.*

2. There is a series of phenomena of fermentation and putrefaction which arise solely from microscopic germs furnished by the atmosphere. These are more especially the formation of mould, of wine-yeast, of the lactic acid ferment, of the ferment which produces the decomposition of urine.

3. Vegetable or animal substances, boiled and closed while hot by means of cotton, remain in that condition quite protected against every kind of fermentation, putrefaction, or formation of mould, if all the germs in them capable of development are destroyed by boiling; for the germs which might reach them from the air are filtered out by the cotton.

4. The germs of most vegetable or animal substances are completely destroyed by simple boiling. A boiling for a short time at 100°C. is also sufficient to kill all germs furnished by the air.

5. But milk, the yellow of egg, and meat, contain germs which are not completely destroyed by a short boiling at 100°. But boiling at a higher temperature under a pressure of two atmospheres in the digestor, or long-continued boiling at 100°, is sufficient to kill even these germs.

6. The germs of milk, yellow of egg, and of meat, even when they have been submitted to a boiling at 100°, not continued, however, too long, are capable of developing themselves as a specific putrefaction ferment, and not unfrequently, at least in the yolk of egg, in the form of long but inert fibrils.

7. This specific putrefying ferment is of animal nature. It develops and increases at the expense of albuminous substances. It is, however, incapable of increase under conditions which are all that are necessary to vegetable formations.

8. The crystallization of supersaturated solutions is commenced or induced by the action of the surface of solid bodies.

9. The induction necessary to set up the crystallization of the soluble hydrates from a supersaturated solution, is less than that necessary for the crystallization of the more difficultly soluble hydrates.

* Liebig's Annalen, March, 1861.

10. The surface of a crystal of the same nature exercises the strongest inducing action. Next to that comes the layer of air which forms on the surface of solid bodies. These coatings are destroyed by heating, continued wetting, or by cleaning, and are only formed slowly again in filtered air.

11. The crystallization of the more soluble hydrates from supersaturated solutions, which is set up even by a feeble induction, only experiences a feeble induction on the surface of the crystal of the same kind, and hence only progresses very slowly.

12. Supersaturated solutions closed with cotton, keep for a long time unchanged, because the cotton filters all the solid particles from the air which gains access. Agitation has no action on the crystallization; it only induces it if supersaturated solutions are in contact with such places of the surface as are fitted to induce the crystallization.

Improvements in the Production of Colors for Dyeing or Printing. (A communication from L. and E. Boilley Frères, of Paris.) JOHN HENRY JOHNSON.

From the London Chemical News, No. 54.

This invention, which appears to us of great value, is for producing from indigo what the inventors term "purple blue." They prepare it from indigo by acting on it with—1. Bisulphate of soda; 2. A mixture of ordinary sulphuric acid with anhydrous phosphoric acid; 3. A mixture of sulphuric acid and chloride of potassium. The first appears to be the best process: it is conducted as follows:—One part of finely powdered and sifted indigo is gradually added, with constant stirring, to from ten to twenty times its weight of anhydrous bisulphate of soda, in a state of fusion at a temperature of from 200° to 300° C. (=392° to 572° F.) [Berzelius recommends preparing the bisulphate of soda by heating 10 parts of dry sulphate of soda with 7 parts of monohydrated sulphuric acid, the temperature of fusion being kept up until the mixture flows quietly at a red heat.—ED.] The fusion of the indigo with the acid salt is continued until the mixture colors water a violet red. The mass is then thrown into water (7 or 8 gallons to each pound of mixture), and well stirred. [Surely the solution should be filtered before proceeding to the next stage.] Two pounds of common salt are now added to the solution for every pound of mixture employed; and, as the solution cools, the color is precipitated in an impure state. This "purple blue" only requires to be well washed to render it sufficiently pure for use. As it is soluble in water, a saline solution must be used for washing. The patentee recommends solutions either of common salt, chloride of potassium, or acetate of potash, for this purpose. "It only remains to filter the liquid in order to collect the precipitate, and to dry the same after having removed the matters which are found on the surface. These matters, which are of a blackish or greenish color, are of another nature, and being of a lighter weight, they will not be deposited until the liquid has been allowed to stand some time. The product thus obtained is in the form of small crystals." Does the patentee mean that the impurity, or the

"purple blue," is crystalline? As it stands in the patent, it would appear to be the impurity. The patentee does not give the slightest information as to the method of employing the color in dyeing or printing. It is probably used in the same way as "carmine of indigo."

Writing Ink.

To the Editor of the *Chemical News*:—

SIR: M. de Champour and M. F. Malepeyre, in their Manual, say that Ribaucourt's ink is one of the best at present in use. The formula for its preparation, which may interest some of your readers, is as follows:—

Aleppo galls, in coarse powder,	8 ounces.
Logwood chips,	4 "
Sulphate of iron,	4 "
Powdered gum-arabic,	3 "
Sulphate of copper,	1 "
Crystallized sugar,	1 "

Boil the galls and logwood together in 12 lbs. of water for an hour, or till half the water has been evaporated; strain the decoction through a hair-sieve, and add the other ingredients; stir till the whole, especially the gum, be dissolved; and then leave at rest for 24 hours, when the ink is to be poured off into glass bottles and carefully corked. I am, &c.,

A COUNTRY SUBSCRIBER.

[A Correspondent, Mr. J. Horsley, has favored us with the following receipt for a good chemical writing fluid:—Triturate in a mortar 36 grains of gallic acid with 3½ ounces of strong decoction of logwood, put it into an 8-ounce bottle, together with 1 ounce of strong ammonia. Next dissolve 1 ounce of sulphate of iron in half an ounce of distilled water by the aid of heat; mix the solutions together by a few minutes agitation, when a good ink will be formed, perfectly clear, which will keep good any length of time without depositing, thickening, or growing mouldy, which latter quality is a great desideratum, as ink undergoing that change becomes worthless. It will not do to mix with ordinary ink, nor must greasy paper be used for writing on with it.—ED. C. N.]

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, February 20, 1862.

John Agnew, Vice President, in the chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

A letter was read from J. K. Whillden, Esq., of Washington, D.C.

Donations to the Library were received from the Statistical Society, and the Society of Arts, London; J. K. Whillden, Esq., Washington City, and Charles Ellet, Jr., Esq., Georgetown, D. C.; Daniel Tredwell, Esq., Cambridge, Mass.; George R. Smith, Esq., Penna. Senate,

Harrisburg, Penna.; H. P. M. Birkinbine, Esq., John W. Nystrom, Esq., Prof. John F. Frazer, and the Mine Hill and Schuylkill Haven Railroad Company, Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's statement of the receipts and payments for the month of January was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (2) were proposed, and the candidates proposed at the last meeting (10) were duly elected.

The Board of Managers reported that they had organized for the present year by electing Washington Jones Chairman, and Messrs. Isaac S. Williams and Wm. A. Drown, Curators, and have appointed the following Standing Committees:—

On Publications.	*On Instruction.*	*Managers Sinking Fund and Finance.*
John C. Cresson,	John F. Frazer,	Frederick Fraley,
B. H. Bartol,	Frederick Fraley,	Samuel V. Merrick,
J. Vaughan Merrick,	Isaac B. Garrigues,	Evans Rogers,
Fairman Rogers,	Alan Wood,	John F. Frazer,
Washington Jones.	George Erety.	George Erety.

The Standing Committees for the ensuing year were appointed by the President, and approved as follows:—

On the Library.	*On Cabinet of Models.*	*On Cabinet of Minerals.*
John Allen,	James Agnew,	Isaac H. Conrad,
Henry Ames,	Wm. B. Bement,	John F. Frazer,
James H. Cresson,	Jos. B. Cooper,	Emile Geyelin,
Geo. M. Conarroe,	James Fraiser,	Isaac B. Garrigues,
George Erety,	H. Hockstrasser,	Henry Hartshorne,
John Ferguson,	John Kile,	John L. LeConte,
Jas. H. Gordon,	F. W. Leaming,	B. Howard Rand,
Raper Hoskins,	Thos. H. McCollin,	R. E. Rogers,
Jas. T. Lukens,	John L. Perkins,	Percival Roberts,
G. L. Martindale.	Coleman Sellers.	J. C. Trautwine.
On Cab. of Arts & Manuf.	*On Exhibitions.*	*On Meetings.*
Daniel Allen,	John E. Addicks,	Wm. H. Brown,
Jas. C. Booth,	John Agnew,	Charles S. Close,
Thos. Bickerton,	Jas. H. Bryson,	D. P. Dieterich,
Henry Bower,	Jas. H. Cresson,	James Dougherty,
R. C. Cornelius,	Wm. A. Drown,	P. G. Eastwick,
C. G. Crane,	John M. Gries,	Robert H. Gratz,
Chas. E. Foster,	Edward Greble,	Henry Howson,
D. M. Hogan,	Wm. Harris,	Washington Jones,
Samuel Sartain,	T. S. Stewart,	Edward Longstreth,
Chas. A. Sharpe.	Isaac S. Williams.	John E. Wootten.

On Meteorology.

Chas. T. Adams,	James A. Meigs,
Chas. M. Cresson,	B. V. Marsh,
T. M. Drysdale,	Fairman Rogers,
John F. Frazer,	James S. Whitney,
Jas. A. Kirkpatrick,	Thomas J. Weygandt.

Mr. Howson exhibited a large model of a Cannon invented by the late Archillius Lawrence, to whose executors a patent has recently been allowed.

The cannon is an improvement on the celebrated Armstrong gun, and is arranged for loading at the breech through a hollow screw, which, when tight, confines a sliding gate against the rear of the barrel.

The gate is so hung to an operating lever as to be rendered self-adjusting, both to the end of the screw and rear of the barrel, and the lever is so connected to a slotted cam on the hollow screw, that by moving this cam in one direction, the screw may be loosened, and the gate at the same time depressed, preparatory to the insertion of the charge; and on moving the cam in the opposite direction, the gate is first raised, and then tightened by the screw.

The cannon has been especially designed with the view of obtaining a perfectly gas-tight packing at the breech.

Mr. Howson also exhibited some remnants of a rifle barrel, to illustrate the results of a recent dangerous experiment.

The barrel was about three-eighths of an inch bore, and the metal over a quarter of an inch thick. The barrel was filled with cartridges, each cartridge consisting of a ball with a charge of powder, and each ball having a hole through it for the reception of a fuse.

The supposition was, that after igniting the powder of the first cartridge, a short time would elapse before the explosion of the second, and so on.

On igniting the first cartridge, however, the whole exploded, and the barrel was rent into a number of pieces, the experimenters narrowly escaping serious injury.

METEOROLOGY.

For the Journal of the Franklin Institute.

The Meteorology of Philadelphia. By JAMES A. KIRKPATRICK, A.M.

JANUARY.—The average temperature of the month of January, 1862, was a little less than one degree above the average temperature of the month for eleven years.

The warmest day of the month was the 1st, of which the mean temperature was 43·8°. The highest degree of heat (54°) was reached on the same day.

The coldest day was the 5th, with a mean temperature of 18·8°. The lowest degree (10°) was reached on the morning of the same day.

The range of temperature for the month was, consequently, 44°.

The temperature was below the freezing point on 22 days of the month, though it rose above that point in the course of the afternoon of every day except five, namely, the 3d to the 6th inclusive, and the

14th. The cold weather during the first week of the month filled the Delaware River with large pieces of floating ice; and the Schuylkill was frozen so tightly as to allow of skating, almost anywhere above the dam. After the 8th, the weather became warm and rainy, and rain or snow fell almost every day until the 22d. From the 15th until the end of the month, the mean temperature was remarkably steady, the lowest being 29° and the highest 36·3°.

The greatest change of temperature in the course of one day was 22°, on the 1st day of the month; the least was 2°, on the 21st. The average daily oscillation of temperature for the month (10·21°) was 1½° below the average oscillation for the month of January, and was less than occurred in that month since the year 1855, when it was but 9·4°.

The greatest mean daily range of temperature was 14·2°, and occurred between the 1st and 2d days of the month; the least was 1·3°, and occurred twice, between the 22d and 23d, and between the 29th and 30th. The average daily range for the month (5·04°) was nearly 1° less than that for January, 1861, and 1½° less than the average range for eleven years. This was the smallest mean daily range observed in any January during the eleven years of observation. The nearest approach to it was 5·5°, in January, 1853.

The pressure of the atmosphere was greatest on the 14th of the month, when the height corrected for temperature was 30·408 inches. The greatest average pressure for a day was 30·404 inches, on the 14th. The pressure was least (29·325 ins.) on the afternoon of the 1st; the average pressure for the day was 29·472 inches. The average pressure for the month (29·922 ins.) was five-hundredths of an inch less than for January, 1861, and nearly four-hundredths of an inch less than the average pressure for January for eleven years.

The greatest mean daily range of atmospheric pressure was 0·594 of an inch, and occurred between the 14th and 15th days of the month; the least was 0·017 of an inch, between the 22d and 23d. The average mean daily range for the month (0·261 in.) was the greatest observed in any January during the eleven years of observation; the nearest approach to it was 0·249 inches in January, 1854. It was three-hundredths of an inch greater than for January of last year, and nearly five-hundredths of an inch greater than the average range for the month for eleven years.

The force of vapor, dew point, and relative humidity were all less than usual. The greatest variation from the average was at 2 P. M.; while at 7 A. M. they were very near the average for the whole period of observation. The force of vapor was greatest (0·275 in.) on the evening of the 12th, and least (0·051 in.) on the evening of the 4th. The average for the month was four-thousandths of an inch below the general average.

The relative humidity was greatest (100 per cent., the atmosphere being completely saturated with moisture,) on the evening of the 29th, during the prevalence of a heavy fog and a drizzling rain. It was